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ART. XXX.—*On the Origin of Prairies;* by JAMES D. DANA.

IN the articles on the Origin of Prairies recently communicated to this Journal by Prof. Winchell and Mr. Lesquereux,[1] presenting independent theories, the view that this origin is in

[1] See for Prof. Winchell's paper, xxxvii, p. 332, and for Mr. Lesquereux's, xxxix, 317, and xl, 23. Prof. Winchell supposes that the soil of the prairies is of lacustrine origin, produced during an epoch of a vast inland fresh-water sea following the glacial epoch; and that in the silt or "slime" of such a sea all pre-existing seed would disappear, so that the vegetation that would spring up over the recovered land would be only that which seeds transported from distant regions would afford, and that this "was more likely to be herbaceous than arboreal."

Mr. Lesquereux holds that the prairie land was recovered from the borders of lakes, rivers, and seas, (fresh or salt), by a process like that exemplified now on the borders of Lake Michigan and the Mississippi, Minnesota and other rivers, in which the region becomes, to a great extent, first a flat of shallow waters, and then a marsh or bog, and that such soil, or mould, owing to the nature of the moss, Confervas, Characeæ, etc., which grow in stagnant waters and contribute to it, becomes next, as a matter of course, covered with sedges and grass. This resulting mould, he observes on p. 318, partakes "as much of the nature of peat as of that of true humus;" it is "impregnated with a large proportion of ulmic acid, produced by the slow decomposition, mostly under water, of aquatic plants;" and "the acid of this soil, by its particularly antiseptic properties, promotes the growth of a group of plants mostly herbaceous," while the want of a free access of oxygen is unfavorable to trees. He adds, "of all the trees, the tamarac is the only species which, in our northern climate, can grow on a peaty ground."

This explanation is stated to cover almost all cases of natural prairies,—those "between the base of the Rocky Mountains and the Mississippi," the "Platas of the Paraguay and Madeyra," the "Pampas of Brazil," "the desert plains of the western salt lakes;" while in "the natural meadows of Holland," "the plains on the shores of the North Sea and the Baltic," "the vast steppes of the Caspian," etc., etc., there are "the same appearances, and the same results of a general identical action, modified only by local and mostly climatic circumstances."

any way due to the dryness of the climate is unnoticed except with the endeavor to set it aside.

The writer, in his Manual of Geology, makes, on the contrary, the degree of moisture the most influential of all causes that tend to determine either the presence of forests or absence of prairies. This idea, although not claimed as original with him,[2] is the result in his mind of original observations made in various parts of the world; and he proposes briefly to state some of the facts in its favor which he has noticed.

On arriving, in 1839, off the north side of the island of Tahiti, one of the first of the Pacific islands visited by the Exploring Expedition under Capt. Wilkes, it was a matter of much surprise that the land, so famed for its tropical fertility and beauty, was bare of trees over the lower ten or fifteen hundred feet of its slopes, the forest trees being confined—the valleys excepted—to regions above this limit. The explanation was at once suggested—that the bare backs forming the sloping surface that lay between the valleys were too dry for trees, in contrast with the region higher up, which was one of very frequent clouds, mists and rains. The existence of forests in the valleys stretching down below the limit accorded with the explanation; for there the declivities were dripping with moisture coming out from between the nearly horizontal layers of the rocks, besides being the courses of many streamlets from the moister region above, and the route of all its rills. Observations afterwards made on the ascent of one of the lofty summits of the island, and on other excursions, confirmed this inference. Over the bare slopes there were no marshy areas; and there was positive proof in the structure of the island, the dip of the rocks beneath being always seaward, and in the nature of the surface, that there never had been such areas; while on the upper slopes, where moisture was abundant, and the ground often boggy, trees were of luxuriant growth.

Similar facts were observed on other Pacific Islands. One of them, Upolu, of the Navigator group, "was covered throughout with forests; or rather it was one dense forest from the extreme east to the west end, and from the water's edge to the very summit of the most rugged peaks. The natives had spread their cocoanut groves and bread fruit trees along the shores, but in many places the line of forests remained yet unbroken. Shrubbery and sugar cane covered some parts of the lower declivities, but there was nowhere a spot of pasture land." Parallel with this condition "the island is in general well-watered.

[2] Among authors who have advocated this view, Professor Guyot may here be mentioned; and since the preparation of this paper, the writer has learned that this eminent physical geographer has in hand a memoir on the connection between the distribution of forests over the world and that of moisture and the causes of the latter.

There is scarcely a day without low and heavy clouds about the summits of the mountains. Many streams of moderate size flow down both sides of the island to the sea, and numerous fountains gush out along the shores.[3]

Again at the Feejee Islands "luxuriant forests cover the elevated parts of the ridges where the frequent rains and more frequent mists and clouds afford them the necessary moisture," while lower down, "the slopes, especially to leeward, are covered with grass;" "the forest vegetation descends lower on the eastern declivities because they are well supplied with moisture from the trade winds—the rain of the southeastern side of Viti Lebu at least trebling that of the opposite side."[4]

The rocks at the Navigators and the Feejees are of volcanic or igneous origin, like those of Tahiti, and similar to the latter in composition and structure.

On the western coast of America the distribution of trees was found to sustain the same view, as the writer has already explained in this Journal.[5] Oregon, along the sea-border, over a breadth of 15 to 25 miles, is mostly covered with forests made up of large evergreens, some of the trees being 300 feet in height and 50 in girt; and the heavy sea-mists extend inland for about the same distance, covering the land the greater part of the time, even through the period of the summer droughts. And on the ascent of the Columbia, there is usually in summer a sudden transition from the mist region to that of clear brazen skies. Residing, in July 1841, at Astoria, within 20 miles of the mouth of the river, for three weeks we had hardly one day clear throughout; and for the following month, at Fort Vancouver, 100 miles from its mouth, we hardly saw a cloud the whole time, and the lofty peaks of St. Helen's and Hood were generally without a cloud to their very top, indicating the dryness of the climate over this interior region.

Beyond the forest border of Oregon, to the eastward, the plains and rolling hills, as those of the Willammet region, are bare of trees, excepting a sparse scattering of oaks, and lines of trees on the borders of the rivers, and along the slope between the upper and lower alluvial flat or terrace. But the higher hills, above one or two thousand feet in elevation, are largely forest-covered; for these, owing to their height and coolness, condense some of the moisture remaining in the sea-winds, and have, compared with the plains below, a moist soil, and the moisture which falls naturally descends along the surface. Farther east, beyond the Cascade Range of mountains, the dryness of the climate is more extreme, and the forests fail altogether

[3] Exploring Expedition Geological Report by the Author. (4to. 1849), p. 314.
[4] Same Report, pp. 339, 340.
[5] For details see same Report, and also this Journal, [2], vii, 387–394, 1849.

except on the high mountains; and at a point on the Columbia river, about 250 miles from its mouth, there is the "last tree" on its banks—the region beyond being seemingly too dry even for the growth of the usual river-bank line of cottonwood.

Thus the fact of a connection between the prevalence of moisture and forests, or of dryness and prairies, seemed to the writer most evident; and it appeared to be a causal connection.

To the southward, in the Sacramento region, and along the coast, a similar system of facts was, later, observed. The dryness of the climate, as is well known, increases southward; the average annual amount of rain along the coast of Oregon is 50 to 60 inches; at San Francisco, California, according to Gibbons, but 22 inches; and farther south on the coast, at the beginning of the California peninsula, but 10 inches. So the forest region of the sea-border narrows southward, failing on the lower lands before reaching San Francisco, and only to be found on the higher hills and mountains where cold and elevation secure moisture from the passing winds; and in the peninsula of Lower California, the mountains even are bare.

In the latitude of San Francisco, and farther south, the Sierra Nevada is generally bare below a line three to four thousand feet above the sea, except in the valleys; above this line there are nearly unbroken forests; and it is stated that 50 to 75 per cent more of rain falls on these mountains than on the Sacramento prairie plains at their western foot. The eastern slope of the Sierra is much drier than the western; and although forests extend nearly to the same line, they are less dense and consist of smaller trees.

The forests, as has been said, reach far down many of the valleys; for the stratification of the rocks leads often to an oozing out of subterranean waters; and sometimes these forests stretch out over the plains below, or form isolated patches in them. The Sacramento plains, which are a score or more of miles in width, are ordinarily covered with grass in scattered tufts, like those of the Willammet, and have in some parts similar "oak-openings." But in one spot, near Feather River, we observed ahead, with some surprise, a thickly-planted grove of oaks. The surprise was removed, on reaching the spot, by finding that the soil below was for some reason quite moist; sufficient to make the grass of the region green, although over the rest of the plain it was then (in November) as dry, and to all appearances as dead, as hay. As the moisture gradually diminished around the borders of the area, the trees were correspondingly more and more widely spaced, and the grass shaded off into the prevailing hay-color.

Other personal observations made abroad might here be mentioned. But we may pass to some well known facts nearer

home which equally sustain the view that forests belong to moist climates, and prairies to those that are comparatively dry.

As America is the moist continent, and correspondingly the forest continent of the globe, as styled by Guyot, so North America itself graduates from forest to prairie land, or the reverse, in parallelism with the variations in moisture. In the United States forests originally prevailed with almost unbroken continuity over the parts which receive the greatest amount of rain with the least amount of evaporation, and prairies or semi-deserts where the amount is small. Over the eastern portion of the continent, from the Gulf states to Labrador, including the most of New England and New York, the Atlantic states, and all of Tennessee and Kentucky, the annual fall of rain is 40 to 45 inches or more; while in Michigan, the state which has afforded many of the facts appealed to by both Professor Winchell and Mr. Lesquereux, it is only 30 inches;[6] in a large part of Ohio, Indiana and Illinois, and in New York toward the St. Lawrence, it is 33 to 40; and beyond the Mississippi west of Kansas and Iowa, it is 25 to 15, and even 10 inches. Parallel with the increase of dryness, as all know, there is an increase in the dominance of prairie land; and the prairies, where the dryness is most extreme, graduate into semi-deserts. Such facts seem surely to prove that natural prairies have some kind of relation to dryness of climate, and that moisture has as much to do with the prevalence of forests.

Over the moister region of New York, and much of New England and other portions of the country, it is common to find not only the hills and upper alluvial plains (or upper terraces of the valleys) covered with forests, where they are still in a state of nature, but even the lower flats bordering the rivers. The writer spent his early life at Utica, N. Y., in the Mohawk valley; and facts sustaining this remark are well exhibited all along that region. Forests still cover some parts of the lower flats, although they have been mostly cut away for purposes of cultivation; and they continue north and south over the upper terraces and on over the high hills. The writer was through the valley the past summer, and observed forest patches on the lower flats (or, where the forests are gone, the old stumps,) at several places between Utica and Herkimer, over the Herkimer flats, between Herkimer and Little Falls, between Little Falls and Johnsville, and also east of Johnsville. These forest patches have generally been left where they occur because these places were too moist or swampy for cultivation, or required more draining than the value of the land seemed to warrant.

West of Utica, near Oriskany, there are large bogs which are so wet the year around that they are hardly penetrable unless

[6] See Blodget's Rain Chart, Army Meteorological Register. 4to, 1855.

when frozen over in winter; and still they are covered with forests.

The soil of these lower flats is often the finest of silt, such as naturally belongs to bogs and lakes; and varies from this on one side to peat, and on the other to sandy loam; and that of the upper terraces and hills varies from sandy loam to gravel and the coarsest and hardest of drift-material. Yet all these different kinds of soil are covered alike with forests. There are small lakes or ponds with their borders of rushes and sedge, swamps, peat bogs, and river bottoms, like those described by Mr. Lesquereux; but none of the swamps, peat bogs and river bottoms, with small exceptions, have become, or show a tendency to become prairies by natural change, however acid or unfavorable for trees the soil may be. The passage is in general from swamp to forest instead of from swamp to prairie.

Dr. Asa Gray, in a recent letter to the writer dated Sauquoit, N. Y., which is in the vicinity of the Mohawk Valley, observes that in the transformation of the bogs of that region (which in part have rush-bordered lakes at centre) to forest land, the tree that in his observation comes farthest out into the bog is uniformly the *Larch*, young trees growing on very shaky treacherous bog; but that, according to J. A. Paine, Jr., an able botanist of Utica, in the North Woods *Black Spruce* extends out as far as the larch. The next tree to the larch, and not far behind it, is the *Arbor-vitæ*, (Thuja occidentalis); the next *Black Ash;* the next *Red Maple*, (Acer rubrum); then, as it grows drier, *Birch;* then *Elm*, (Ulmus Americana). Alder, which runs out on the bog almost as far as the larch, is not here counted, it being regarded as a shrub. The "Cedar" (Arbor-vitæ) swamps, which are the remnants of the very extensive ones of Parishhill and Sangerfield, and from which the cedar has been cut out, and which are gradually drying, are already becoming filled with black ash, with a sprinkling of red maple, and especially of elm.

The great lake regions of Maine afford facts of similar import. I cite the following from observations made the last summer, at the suggestion of the writer, by Prof. A. E. Verrill, of Norway in Maine, (now of Yale College), and communicated by him (from Westport, N. Y., on Lake Champlain,) for this article:

"The points which I had in view in my observations were the following: 1st, the succession of vegetation as a lake changes to a swamp, and then to dry land; 2nd, when swamps become permanently flooded what changes occur in the vegetation; 3d, when lakes or swamps are drained what effects are produced; 4th, whether natural meadows are ever produced in our climate, and under what circumstances will grass or trees flourish best.

There are in Maine abundant opportunities for studying almost every

change which can occur independent of climate in the vegetation of the lake margins, swamps, and meadows, both recent and ancient.

Near Norway I found a lake, one part of which has been gradually changing to a bog, and presenting all gradations from the open lake to a comparatively dry swamp. Approaching the bog, the water becomes shoal and the bottom is composed of black, soft vegetable mud of great depth, the surface of the mud supporting a variety of aquatic plants in patches. In still shoaler water clumps of sedges and rushes appear collecting around old stumps, driftwood, &c., and at the same point there are spots where various Ericaceous shrubs (such as Andromeda polifolia, Kalmia glauca, Cassandra calyculata, Ledum palustre, &c.). with the Alder (Alnus incana) begin to form dense patches of shrubbery bog-land. Back of this these patches begin to blend, and other species are added to the shrubs, while the drift logs, &c., give support to an abundance of sphagnum and herbaceous plants, and now trees of Arbor-vitæ and Swamp-ash begin to find support, first taking root apparently on the old logs overgrown with vegetation and covered with mould, but the roots extend downward into the soft mud and water. Both these trees will grow where their roots, and even the bases of their trunks, are continually bathed in water. Farther back in the swamp these two trees become larger and more dense, and are mixed with fir, alder, larch, and an occasional white-pine and hemlock; the latter, however, only becomes common upon the drier borders of the swamp. The red maple also often grows in these swamps, in the firmer spots. Many other shrubs also occur, such as Rhodora Canadensis, Kalmia angustifolia, Vaccinum (several species), Myrica Gale, &c. The entire assemblage constitutes a dense forest with thick underbrush. Some of the Arbor-vitæ grow to a diameter of three feet, and the Ash to 15 or 18 inches, in the wettest parts.

The final condition of this kind of swamp may be seen in another place a few miles distant, where an extensive meadow has been formed by clearing a portion of such a swamp in a farther advanced stage, and partially draining it. This has been cleared about fifty years. It was formerly covered by a forest similar to that described, and some portions still remain in the original condition. Other parts that have been neglected have grown up to thickets of alder, white birch, American aspen, and other trees. The grassy portion covers 300 acres, or more, and in many parts is still quite wet and soft. The soil is composed of peat and muck which in many places has been penetrated to the depth of 6 or 8 feet, and is doubtless deeper in some parts. On some patches of low clayey soil, originally islands or low points of land, there are dense thickets of larch.

In the same region there is another extensive meadow surrounded by high, well defined banks of drift material, often terraced, and forming apparently the bottom of an ancient lake at the close of the Drift period. The lower parts of this basin are occupied by extensive swamps, similar to those already described, while other parts, composed of sandy soil and somewhat higher, were originally covered with a heavy forest of Pine. There is no evidence that grass ever grew upon any part of it until cleared by man.

I have observed some cases where lands have been flowed by means of dams at the outlets of lakes. In these cases, those trees, even of swamp-

ash and arbor-vitæ, which have their trunks submerged to the depth of two or three feet are invariably killed after some time.

I have met with but two cases of lakes recently drained. In one of these, a heavy crop of grass was produced the first year, chiefly of "blue-joint," if I remember rightly, but in subsequent years the lake bottom grew up with great rapidity to a thicket of alder, willow, poplar, &c.

In the other case, coarse grass, sedges and other herbaceous plants prevailed for a year or two but very soon gave place to a rank growth of various forest trees, including alder, white birch, willow, poplar, red maple, &c.—the alder and willow growing most rapidly. I have no reason for supposing that the trees *did not vegetate the first year;* they became conspicuous as they grew higher than the grass and other herbaceous plants.

All of the phenomena observed in Maine also appear in this region.

On the coast of Labrador, and especially at Anticosti, very extensive peat-bogs occur under similar circumstances. On the southeastern side of Anticosti there is a bog bordering the coast for 70 or 80 miles, and often 7 or 8 miles wide, composed of peat of considerable thickness where exposed by the encroachment of the sea. In the midst of these bogs there are often small lakes or pools of stagnant water. The surface of the bogs or heaths is covered thickly by sphagnum and by a variety of Ericaceous shrubs. Vaccinum, (several species), Kalmia, Rhodora, Ledum, Rubus, Chamæmorus, &c., abound. Occasionally in the shallow pools and in wet depressions there are patches of sedges and coarse grasses; but dense clumps of alder, larch and other trees occur scattered over the surface, while immediately about the shores of the lakes there are usually dense thickets of these trees mingled with some spruce and white-birch (canoe birch). The last two trees form the chief part of the forests away from the bogs. In no case have I observed patches of grassy land occurring naturally of any considerable extent away from the immediate sea-shore. But the coast of Anticosti is everywhere fringed by a belt of coarse grass, (Elymus mollis, &c.,) mingled with various flowering plants. This belt sometimes widens into large patches at the mouths of streams.

The smaller low islands that are occasionally swept by the spray, usually support a dense growth of the same grasses and herbs, but the higher islands, as well as those of larger size, are covered by thickets of spruce, fir, larch and birch.

From these facts you can draw whatever conclusion you may think justifiable; but I think it evident that in our climate trees will invariably vegetate in the wettest soil and even displace grass where it has already become established."

The facts described by Prof. Verrill are so full and explicit in favor of the possibility of lakes, peat-lands and swamps, passing at times directly to forest land, that it is unnecessary to cite additional observations.

In this connection it is important to note some of the conditions essential to the self-propagation of trees. We mention a few well-known facts:

a. Elms, maples, and other shade trees drop their fruit profusely over a grass-covered lawn, and yet none take root. The grass prevents the seeds for the most part from reaching the soil; or if washed into it by rains, the pre-occupation by the grass hinders their development.

b. But along the sides of an earth-made path, and in shaded places, as near a fence or hedge, a crop of young plants will often spring up.

c. These young plants, as the writer has observed about his own grounds, die off during an ordinary summer's drought. Only those which spring up where the earth is kept moist by the shade and the position is one favorable for perpetuated moisture, and those which fall into the open and enriched soil of a garden, will stand the usual summer's drought and live.

d. The simple fact is that the roots of most trees are slender and rather sparingly branched, and the leaves also are few; and unless they have a chance to strike deep before a drought, down to depths where there is permanent moisture, and take considerable expansion at such depths, they are cut off by the dry season. Even if a peculiarly wet summer favors the seedlings so that they get a year's start, the drought of the following year is almost sure to cut them down.

In view of the facts we believe we are safe in deducing the following conclusions:

1. *A prevalence of moisture is connected directly with a prevalence of forests.*—This is exhibited in the distribution of forests over the surface of the continent; on mountains; down the valleys of mountains, where outcropping layers bring moisture to the surface; along the slopes dividing the alluvial terraces of many prairie regions, where moisture oozes out for the same reason—the stratification of the alluvium; over many prairie plains when they are unusually moist; and along the banks of rivers, which feel even the narrow fogs that may overlie the stream.

To avoid misapprehension of this statement it should be considered that this moist condition is not proportioned necessarily to the annual fall of rain and snow. For the mists which prevail throughout the year along some sea-coasts, and in some mountainous regions, may not drop half the amount of moisture in a year that descends through rain and snow in other regions, and still be vastly more favorable for forests. The mist keeps the ground always moist. The rains, on the contrary, may descend plentifully during half the year and give a large number of inches of fall, and yet be followed by a season of drought unfavorable to forests. Moreover, a large part of the waters of rivers flow off in the streams to distant regions; while the more

gently distilling mists keep the ground thoroughly wet, and lose much less by running off. Hence, the regions of the greatest fall of moisture on a rain-chart do not necessarily correspond with those of the greatest extent of forests. The area of even "45 inches" over the United States is not necessarily, therefore, an area throughout of forests.

Again, the effects of the falls of moisture in the shape of rain mists, &c. depend much on the heat of the region, because of the consequent difference in evaporation. With a cool climate, like that of the coast of Oregon, there is comparatively little evaporation, and the moisture lies long in the soil. But the same moisture, from the same kind of mists, on a coast like that of Peru should produce much less effect. Forty inches of rain in a year about a mountainous region, or in a cool climate, would have far greater effect toward keeping the soil moist than in those low lands which lie in the same latitudes in the Mississippi valley. It has been stated that the amount of rain-fall in the Sierra Nevada is 50 to 75 p. c. more than in the Sacramento and Joachim plain on the east; but the effect of this moisture on vegetation is vastly greater than this on account of the cooler climate of the heights.

2. *In a moist region soils of all kinds not under water may become forest-covered, from the finest silt to the coarsest and loosest gravel, from the sourest marsh mud and drying peat swamp to the most fertile alluvium.*—This is shown through eastern North America, and has been illustrated by reference to facts in the States of New York and Maine.

Yet, where there is only a moderate supply of moisture, the different kinds of soil will manifest their differences in unlike productiveness in trees. The loose gravel is quick to feel droughts; the clayey soil much less so; the best vegetable mould still less so. The fact that trees will not grow over soils permanently submerged does not require us to admit that when the same region has become comparatively dry the soil is still unfit for trees. When, on the first recovery of the land, grass takes possession of the surface, forests, in moist regions, may soon spread and dispossess it.

3. *Grass-regions may encroach on forest-regions, or the reverse, according to the dryness or moistness of the country.*—Where the ground is permanently moist, the meadow seldom makes progress against the trees. Thus the line of forest which covers the slope lying between two terraces, so striking a feature in some prairie regions, holds its place notwithstanding the grass of the prairie plain above, and of that below it.

But if the old forest covers dry soil, the grass, or its precursors in other plants, may gradually make an undergrowth among the nearer trees, and thus commence encroachment. Droughts

do not destroy the grass, while they do the seedlings of the trees; and when, under such conditions, the old trees die, they die without successors. The encroachment is the slow work of centuries, because the standing trees are not injured by such an undergrowth. They live out their life-time, if left to nature, and only when they die does the meadow-surface complete itself.

The forest, as has been explained, cannot ordinarily encroach on the prairie. But if a prairie, through any change of circumstances, becomes permanently wet, so decidedly so as to weaken the grass, but not a region of permanent water, then the forest has its chance for encroachment.

4. *If moistness, then, is especially favorable to the growth of forests, a change in the moistness of a region occasioned by geological events would be attended by a change in the adaptedness to such growth.*—The Champlain epoch of the Post-tertiary, when portions of the continent over the higher latitudes were much depressed, (in many parts 300 to 400 feet), and the more southern much less so, and when the great upper terrace flats of our lakes and rivers, often many miles in width, were made, was a time of warmer climate over the continents than the present, as the distribution of the terrestrial animal life of the era proves.[6]

It was, also, as the same terraces and the raised beaches prove, an era of wider expanse of lakes and rivers over the land. It was, therefore, in all probability, an era of moister climate over these regions than now. This being so, it was an era eminently favorable for the growth and extension of forests, when trees would have taken possession of the dry land not under water; that is, wherever it was *not too dry*, as even then was probably true of the far west. Now, after this Champlain epoch of depression, an elevation of the land began, bringing the continent up toward its present level, causing a change of climate to one of greater coolness and dryness, draining extensive regions that had been under water, and drying moist areas. Consequently, there would have been, from the beginning of this change, a tendency to a narrowing of the forest regions; and, with such a tendency, an actual narrowing would, in one region or another, have begun.

As the various parts of the continent would have differed hygrometrically during the Champlain epoch in the same way as now, the great dense forests of the continent, on this side of the Rocky Mountains, would have then, as now, covered the eastern portions, and the great treeless regions would have been beyond the Mississippi. Any subsequent extension of the *prairies* that accompanied the approach to the present era and condition would, therefore, have been from the west toward the east. The prairies would have gradually stretched their bare surfaces

[6] See the author's Manual of Geology, pages 547 to 567.

along the rivers, and made their winding way eastward among forest-clad hills, wherever the dryness of the soil most favored them. There would thus have been a slow yielding of the soil to plants that could hold their places in spite of droughts.

At the same time the new-made lands about drying bogs, lake shores, etc. would have taken their vegetation from the adjoining regions; the kind being determined by the dryness or moistness of the region through the year; by the nature of the vegetation that was most accessible with its seeds; by the character of the soil; or, if either the dryness of the climate, or its moistness, were great, very largely by this one element alone, the dryness determining the absence of trees in spite of all other conditions, and the moistness their presence. Accordingly, there are interminable forests in Eastern America, interminable prairies on the slopes of the Rocky Mountains, and in the region between an intermingling of forests and prairies.

The species of the Post-tertiary trees, as may be concluded from the observations on buried fragments, were probably identical for the most part, if not wholly, with those now existing, (as is true also of the species of invertebrate animal life). Our forests of modern trees date, beyond reasonable doubt, from this remote Post-tertiary era. Their distribution began then, and in accordance with the favoring conditions of the soil and climate. At the present time, we have the distribution of that era as it has become after being modified by the effects of subsequent changes of level and of climate.

But the modifications from these causes are, even now, far from being completed. As is well known, there are extensive forest regions where the soil and climate are so dry that if the trees were cut away they would not be able to re-establish themselves. A conformity between the distribution of trees and the climate is, consequently, only partially accomplished. Any cause that destroys the trees of a region, be it tempest, fire, or other agency, helps on this progress.

The prairies of the Willammet, and in part those of the Sacramento, and also many east of the Rocky Mountains, have now their "oak-openings," or surfaces scattered over with oaks, 15 to 20 or so, to an acre. But these trees may once have been in thick groves, as they are now clustered near Feather River, in the Sacramento region. (p. 296.)

A continent, or a large portion of it, cannot pass from a condition of greater to one of less moisture without ultimately exhibiting it in the distribution of its forests and prairies.

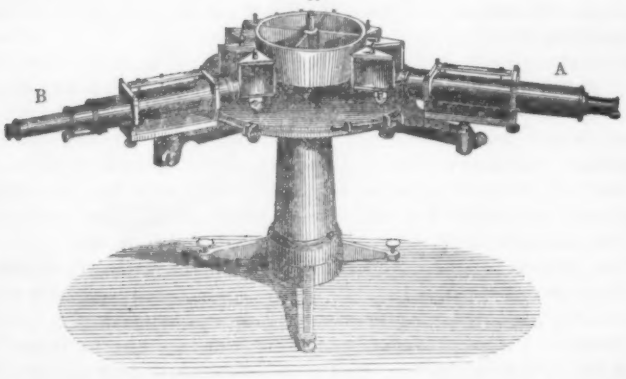
It is, therefore, no objection to the theory here propounded, that forests, when cut down, do not, if left to nature, always resume their places, but give way to meadows. The times since the original planting are changed, and meadows are on the increase from natural causes, as well as through the agency of man.

ART. XXXI.—*On the Construction of a Spectroscope with a number of prisms, by which the angle of minimum deviation for any ray may be accurately measured and its position in the solar spectrum determined;* by JOSIAH P. COOKE, Jr.

IN an extract from a letter of the author published in this Journal, vol. xxxvi, p. 266, a method of adjusting the prisms of a compound spectroscope was described, by which the adjustment for any portion of the spectrum could be obtained with great rapidity and accuracy. A further study of the subject has shown that the method of adjustment then only briefly described admits of the highest precision, and may be applied to the exact measurement of the angle of minimum deviation of the spectrum rays. It has been thus possible to apply the great dispersive power of the large Cambridge spectroscope in determining the relative position of the various spectrum lines, and to secure all the accuracy of which angular measurements are capable. The value of such measurements is obvious, and with the hope that this method will prove to be an assistance to investigators we propose to give in this paper a description of our instrument and of the manner of using it.

The general construction of the instrument is shown in fig. 1.

1.

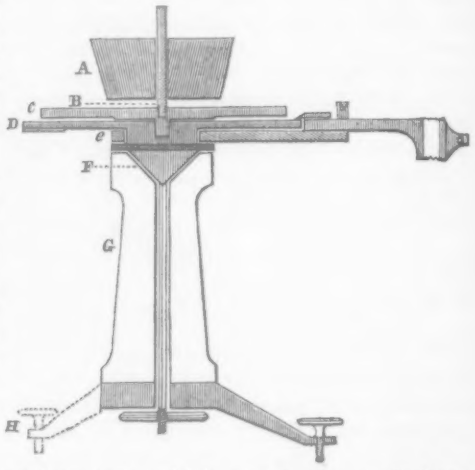


The two telescopes are constructed in the usual way. The telescope A, which we shall call the collimator, has an adjustable slit placed exactly at the focus of the object glass. The small tube which carries the slit slides into the body of the telescope, but a rack and pinion motion would be preferable, so that when the focus is changed the slit will necessarily remain vertical. The rays of light diverging from the slit and rendered parallel by the object glass of the collimator next pass through

a series of prisms adjusted around a conical wheel, which will be soon described, and are then received by the telescope B. The spectrum, which is formed at the focus of the object glass of this telescope, is examined with eye-pieces of different magnifying powers in the usual way. The object glasses of the telescopes are $2\frac{1}{4}$ inches in diameter and have a focal length of $15\frac{1}{2}$ inches. They rest in Y's and are provided with spirit levels and adjusting screws. The frames which hold the telescopes are supported on pivots turning in sockets at the ends of two arms connected with the body of the instrument and may be clamped in any position. The arm which carries the collimator is permanently attached to the main iron plate, but the arm, which carries the observing telescope may be moved around the plate.

The details of the construction are shown in fig. 2, which is a section made through one of the legs of the tripod and the movable arm, the telescope with its frame and pivot having first been removed from the socket. (This figure as well as fig. 4 were drawn to the scale of one inch to a foot). The parts are as follows: H is an iron tripod with leveling screws; G is a hollow mahogany column with a conical cavity at the top; F is an iron cone which rests in the conical cavity, supporting the whole body of the instrument and connected by a long iron rod with a clamping screw beneath the tripod. By means of this arrangement the instrument may be turned as a whole in the horizontal plane and the collimator directed to the source of light. Above the iron cone and fastened to it securely is the main circular plate of the instrument, which is 18 inches in diameter and $\frac{1}{2}$ an inch in thickness. Near the outer edge of this plate is inserted a band of silver, which is graduated to 10″ of arc. On the under part of the plate there is a neck and at the center of the upper surface a socket, which are accurately centered with each other and with the graduated limb. Around the neck at E moves an iron collar, to which is attached the arm bearing the observing telescope. This moves, therefore.

2.

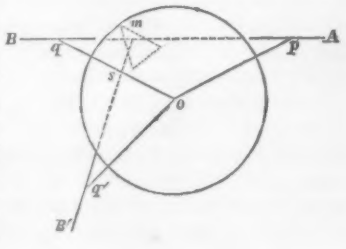


concentric with the graduated limb and bears a vernier by which the angular motion may be determined, reading to 10″. In the socket of the first plate rests the pivot of a second plate, C, which turns on the first and supports the prisms with the adjusting wheel A. The diameter of the upper plate is an inch less than that of the lower plate, so as to expose the graduated arc near the outer edge of the latter, and its upper surface is as flat and even as possible. Rising from the center of the upper plate there is a tall screw pivot of iron, B, on which turns a conical wheel, made also of iron. By this motion the wheel may be either raised or lowered. This wheel is an essential portion of the instrument, and we will next consider the theory of its use.

In the ordinary method of measuring the angle of minimum deviation with a Babinet's goniometer the prism is placed on a revolving plate at the center of the graduated circle, and so adjusted that the edge of the refracting angle shall be perpendicular to the plane of the circle, and its bisectrix parallel with a diameter of the circle. The axis of the collimator and observing telescopes, moreover, being parallel with a diameter of the circle, it is evident that, when the prism and telescope are turned into the position of minimum deviation, the vertex of the angle of minimum deviation will coincide with the center of the circle, and hence the arc intercepted between two radii of the circle parallel to the axes of the two telescopes will be the measure of the angle required. This angle is practically measured by first bringing into line of collimation the observing telescope and collimator, so that the image of the slit at the end of the collimator coincides with the vertical wire in the eye-piece of the telescope. The position of the vernier on the graduated arc is now noted. Then, having adjusted the prism, both the prism and the telescope are turned to the position of minimum deviation, and a coincidence established between the vertical wire and one of the lines of the spectrum. The vernier is now again read and the difference between the two readings is the angle of minimum deviation for the ray corresponding to that line.

It will be obvious however from fig. 3, that it is not necessary for the accuracy of this measure either that the prism should be placed at the center of the circle, or that the axes of the telescope should be parallel to one of its radii. If only the bisectrix of the refracting angle passes through the center of the circle, the prism

3.



may be placed on the outer rim of the plate, and if only the radial arm, which carries the observing telescope, moves concentric with the graduated arc, the axis of the telescopes themselves may make any angle with the radius whatever. Let Op and Oq be two radii of the graduated circle. Let Ap and Bq represent the axes of the two telescopes in collimation and making any undetermined angles with the two radii. Place now a prism at m and turn the radial arm Oq into the position Oq', but without changing the inclination of the axis of the telescope to the arm, and let BmB' be the angle of minimum deviation. Since now the two triangles qsm and $q'so$ are similar, it is evident that the angle BmB' is equal to the angle qoq', and is therefore measured by the arc intercepted between the radii Oq and Oq'.

In order now to apply this principle in the spectroscope the glass prisms were mounted permanently in brass frames. The frames rest on three brass pins which were adjusted by filing until the refracting edge of the prism was perpendicular to the iron place C fig. 2. Two brass pins were also attached to the back of each prism and the lengths of these so adjusted that, when the prisms are pushed against the conical wheel, the bisectrix of the refracting angle should coincide with a radius of the wheel. The last adjustment was made with the aid of a guage cut from a sheet of tinned iron fitting at the same time the periphery of the wheel and the face of the prism, which was applied alternately on either side. The angle of minimum deviation of the ray D was then measured for each prism in the following way:—

The prism having been placed on the plate with the pins applied to the periphery of the wheel, the collimator was turned on its pivot, and at the same time the plate C turned on its center, until on applying the eye at the open slit and looking through the object-glass towards the prism, the further back edge of the prism, seen through the glass of the prism, appeared to coincide with the nearer back edge seen directly. When this is the case, it is evident that the rays of light which reach the eye from the further back edge of the prism must pass through the glass parallel to the back edge of the prism, or, what amounts to the same thing, perpendicular to the bisectrix of the refracting angle, and when the light passes in this way the prism is at the angle of minimum deviation. When the prism was thus placed the collimator was turned slightly on its pivot until the axis of the telescope prolonged passed through the center of the prism-face, and was then securely clamped in this position. This adjustment may be made with sufficient accuracy by the unassisted eye. The prism having now been turned one side, the arm of the observing telescope was turned on its center, and at the same time the telescope turned on its pivot until it came into exact collimation with

the collimator. In order to facilitate this adjustment the telescopes are provided with caps which cover the object-glasses of the telescopes with the exception of a narrow vertical slit at the center. The pivot of the observing telescope was next clamped and the caps having been removed the image of the slit seen through the observing telescope was brought into exact coincidence with the vertical wire and the position of the vernier noted. The prism was now brought back to its place by turning the upper plate of the instrument, and the observing telescope also turned until the position of minimum deviation for the ray D was attained and this well known double line brought to coincide with the vertical wire. The limb was then again read, and the difference of the two readings gave the angle of minimum deviation for the prism.

In order to show that this method of measurement is perfectly accurate, we give below the angles of minimum deviation of the nine prisms of the Cambridge spectroscope measured as just described, and in a parallel column the same angles measured in the old way with the prisms at the center of the plate. It will be seen that the differences are insignificant and within the limits of error of observation:

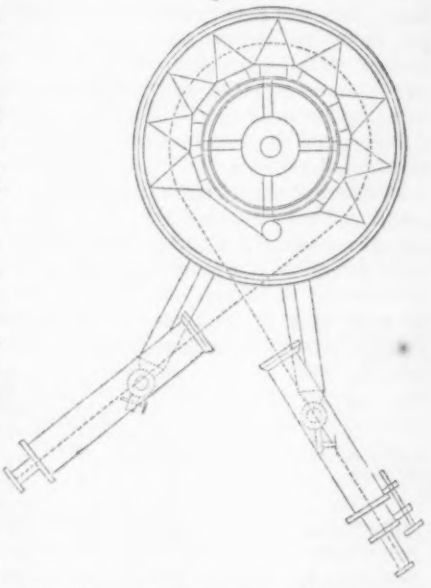
	Measured at center of plate.	Measured on edge of plate.	
No. 1,	29° 31′ 10″	29° 31′ 10″	
No. 2,	29° 29′ 10″	29° 29′ 10″	
No. 3,	29° 28′ 10″	29° 28′ 10″	
No. 4,	29° 37′ 0″	29° 36′ 40″	−20″
No. 5,	29° 28′ 30″	29° 28′ 40″	+10″
No. 6,	29° 36′ 30″	29° 36′ 10″	−20″
No. 7,	29° 28′ 10″	29° 28′ 10″	
No. 8,	29° 29′ 30″	29° 29′ 40″	+10″
No. 9,	29° 28′ 40″	29° 29′ 40″	
	267° 37′ 50″	267° 37′ 30″	−20″

Although the adjustments required may appear complicated, they can be made in far less time than it has taken to describe the method.

It is a well known fact that when a beam of homogeneous light passes through a prism at the angle of minimum deviation the incident and emerging pencils make the same angle with the faces of the prism, at which they respectfully enter and leave the glass. Hence a second prism like the first stands in the same relation to the emerging beam in which the first stands to the incident beam. If then, after the first prism has been adjusted at the angle of minimum deviation a second prism be applied against the wheel at the side of the first, by moving the prism slighly to one side or the other, it will be easy to find a position, in which this prism also is at the angle of minimum devia-

tion, moving of course the prism on the plate without disturbing the position of the plate itself. In like manner other prisms may be added until the required number is obtained. (In the Cambridge spectroscope there are nine glass prisms of 45°, as shown in fig. 4.) This adjustment has only to be made, however, once for all, since when the prisms are adjusted they are fastened to a very thin, flexible brass ribbon, which, passing through a box at the back of each prism, is there secured by clamping screws. The ends of this ribbon, moreover, are attached to a small brass drum, which, being wound up by an ordinary clock spring, draws the chain of prisms tightly around the conical wheel, and keeps them always in place. By tracing the path of a ray of homogeneous light through a series of similar prisms, as is shown in fig. 4, it will be found that the path of the ray within the prisms is always tangent to the same circle, provided that it passes through all under the conditions of least deviation. Assuming, then, that the distances between the prisms are invariable, as they must be when the prisms are fastened to a brass ribbon as just described, it will be evident from a moment's reflection that the greater the refrangibility of the given ray the less must be the diameter of the circle, around which the prisms should be arranged in order that the ray may pass under the required conditions, and, knowing the dimensions of the prisms as well as the index of refraction and dispersive power of the glass, it is easy to calculate approximatively what the diameter should be in a given case. The dimensions of the conical wheel A, fig. 2, were thus determined—the largest diameter, $9\frac{1}{2}$ inches, corresponding to the extreme red, and the smallest diameter, $8\frac{1}{2}$ inches corresponding to the extreme violet rays of the solar spectrum. In order to facilitate the adjustment a series of lines were engraved encir-

Fig. 4.



cling the wheel at equal distances from each other and numbered from 1 to 12.

Having described the construction of the instrument it will now be easy to understand the method of using it. Let us suppose that the object is to measure the angle of minimum deviation of the blue ray of the strontium spectrum. By examining any chart of the spectra of the chemical elements it will be found that this line is situated roughly at somewhat less than two-thirds of the distance from A to H. If, then, we turn the conical wheel until the pins of the prisms all rest against the line marked 7, we shall have approximatively the true position. We then adjust the collimator with reference to the first prism exactly as before described for a single prism. Turning then the upper plate so as to remove the prisms out of range, we bring the observing telescope into collimation with the collimator, as also before described, when on reading off the limb we have the starting point for our measure. We next turn the plate and move the telescope until the spectrum appears in the field, and carefully bring the blue line to coincide with the vertical wire at the position of minimum deviation. We now raise or lower the conical wheel and notice if in this way the angular deviation is diminished, and leave the wheel in the position where the minimum is reached. It now only remains to again read the limb when the difference of the two readings subtracted from 360° will give the angular deviation required.

When near the position of minimum deviation a large motion of the conical wheel produces only a slight motion of the image, so that after a table has been made giving the position of the wheel for a few of the marked lines of the spectrum it is always possible to bring the wheel at starting to the desired point. Moreover, the fact that when near the position of minimum deviation the position of the image is affected so slightly by a small change in the position of the prisms, renders it possible to make all the adjustments required with exceeding rapidity and accuracy.

In order to test the accuracy of our method we have made several determinations of the minimum deviation of the line D, and although between each determination the whole apparatus was completely dismounted, the value obtained was in all cases 267° 37′ 50″.[1] It will be remembered that the sum of the angles measured on each prism separately at the center of the plate, as given on page 309, is precisely the same (267° 37′ 50″) and the sum of those measured on the edge of the plate (267° 37′ 30″) only differs from this by 20″.

When it is not important to use absolutely the whole aperture of the prisms it is not necessary to change the position of the collimator in passing from one part of the spectrum to an-

[1] As the mean of the two lines.

other. If we adjust the collimator as above described, when the prisms rest against the middle circle on the wheel, the whole spectrum can be passed under review with great rapidity without any further change of the collimator, and each point seen under the condition of minimum deviation. When, however, on account of the feebleness of the light it is important to use the whole aperture of the prisms, a slight gain can be obtained by readjusting the collimator at the extreme points of the spectrum. In making the measurements described in this paper, an important advantage is gained in keeping the position of the collimator fixed; for if its position is changed, the point to which the angular measurements are referred is changed also, and must be determined anew. If however the arms, to which the telescopes are attached, are so arranged with a sliding motion that both the collimator and the observing telescope may be moved parallel to themselves without altering their relative angular position, the whole aperture of the prisms may at any time be used, and nevertheless all the measurements referred to the same point on the graduated limb.

Besides the set of glass prisms the Cambridge spectroscope is also provided with a set of sulphid of carbon prisms, which have been previously described in this Journal. They are mounted on a separate plate with a separate wheel of the proper dimensions and are arranged in all respects like the glass prisms above described. The plates are provided with handles so that one battery of prisms may be quickly lifted off from the instrument and the other put in its place. But although the liquid prisms are valuable on account of their great dispersive power in bringing out faint lines, especially in the more luminous portions of the spectrum, yet their use is very restricted. One difficulty arises from the immensely rapid change of the index of refraction of sulphid of carbon with the slightest change of temperature. We have noticed within half an hour on a summer's day a change of 8′ in the angle of minimum deviation of a single sulphid of carbon prism of 45°, although the temperature of the room had only in the meantime changed eight tenths of a Centigrade degree. The temperature of the prism undoubtedly changed much more than this; but when we remember that the variation thus produced would amount to over one degree for the nine prisms, it will be seen that they must be useless for any purposes of direct measurement. Again, sulphid of carbon is far less transparent than glass to the more refrangible rays of the spectrum, and lastly, a slight change of temperature in the observing chamber produces at once currents in the liquid, which are fatal to good definition. Nevertheless under the best conditions, we have found that sulphid of carbon prisms define as well or even better than glass. The instrument

described in this paper, with the exception of the glass prisms, was made by Messrs. Clark & Sons of Cambridgeport, and we would here especially express our indebtedness to Mr. George Clark for his great ingenuity in planning and executing the mechanical details. We reserve for another article an account of the results of our measurements.

ART. XXXII.—*Experiments in Mechanical Polarity;* by PLINY EARLE CHASE, M.A., S.P.A.S.[1]

I HAVE already published three simple experiments in mechanical polarization (Proc. Amer. Philos. Soc., ix, 359), and I have endeavored in various ways to show that terrestrial magnetism is probably owing to an analogous polarization of aerial and aetherial currents. Finding that my hypothesis was sustained by some remarkable numerical coincidences, as well as by various points of correspondence between the assumed influence of gravitation-currents and the observed daily variations of declination and inclination, I sought for some practical demonstration of the truth of my inferences. I therefore endeavored to imitate the movements of the atmosphere by mechanical contrivances, and the results, which are in most respects such as I anticipated, and which are all susceptible of an easy explanation, are embodied in the following additional experiments.

4. By the use of fans, bellows and blowers of various kinds, either alone or in conjunction with directing discs, currents may be produced that will deflect the needle in any desired direction, in accordance with simple and evident mechanical laws.

5. I have tried iron, copper, wood, zinc, and pasteboard, and find, as I anticipated, that the material employed for producing or directing the artificial currents has no effect upon their mere *mechanical* action, but I have found the results most satisfactory when, in order to avoid the complication of induced magnetism or electricity, I employed non-conductors, such as wood and pasteboard. Upon subsequently repeating the experiments with different metals, the effects of the induced currents have been plainly shown.

6. Increasing the number of directing discs (provided they are all parallel), often modifies the intensity of current-influence, but does not appear otherwise to affect the result.

The most striking developments that I have yet hit upon, were obtained by the aid of a Gaussian modification of Faraday's apparatus for showing the electric currents developed in moving metallic bodies by terrestrial magnetism. It consists of a heavy

[1] From the Proceedings of the American Philosophical Society, July 21, 1865.

copper ring (*a*), fixed to horizontal supports (*b*) (*c*), on which it can be rapidly rotated by a wheel (*d*) and pinion (*e*), the supports being relieved by friction-wheels (*f*). The outer diameter of the ring is 6 inches at each edge, and $6\frac{3}{16}$ inches in the middle; the inner diameter 5 inches; the thickness $1\frac{1}{2}$ inches. The axle opposite to the gearing (*g*), is hollow, to allow the insertion of a brass rod (*h*), which supports a compass (*i*) horizontally in the interior of the ring. The compass is not shielded by a glass, and it is therefore easily affected by aerial currents. If the ring is made to revolve around the compass needle, the N. pole of the needle is deflected in a direction opposite to the motion of the top of the ring.

For my special purpose, I replaced this copper ring by a wooden one of the same dimensions, and prepared a number of discs (*k*) (*l*), in the form of semicircles and circular segments, fitted so that they could be fixed, in different vertical positions, in the compass box, above the needle. Causing the wheel to rotate, with the axis variously placed, I tried the following experiments:—

A. Single disc, or multiple and parallel discs.

a. Axis in magnetic meridian.

7. When the disc was in the meridian, the currents produced a slight tendency in the needle[2] to move in the same direction as the upper part of the ring.

8. When the disc was in the equator, the slight tendency was opposite to that in Exp. 7, and the same as if it had been produced by induced electricity in the ring.

9. When the disc was inclined to the meridian, there was a marked polarity, perpendicular to the disc.

b. Axis in magnetic equator.

10. The disc being placed in the meridian, there was no disturbing current.

11. Placing the disc equatorially, the needle was still undisturbed.

12. But when the disc was inclined to the meridian, the current-polarity was parallel to the disc.

c. Axis 45° from magnetic meridian.

13. In nearly all positions of the disc, there appears to be a disposition in the needle to move *from* the axis of the ring. But when the disc is in or very near the meridian, there is a slight tendency towards the axis.

In order to imitate more closely the earth's principal thermal radiation-planes, which are all theoretically parallel with the

[2] In speaking of the needle's tendency, I always refer to the motion of the N. pole.

thermal meridians and meet at the thermal pole, I constructed a compound disc (*m*), of two circular segments, inclined to each other at an angle of about 30°, with which I tried the following experiments:—

B. Spherical-angular disc.

a. Axis in magnetic meridian.

14. If the disc is so placed, with its opening towards the south, that its angle is bisected by the meridian, the current-polarity carries the needle in the same direction as the motion of the top of the ring.

15. If the opening of the disc is turned to the north, the apparatus remaining in other respects as in the last experiment, the current-polarity is reversed (as in Exp. 8).

16. Placing the disc equatorially, I am unable to discover any current-polarity.

17. Inclining the disc towards N.W. and S.E., the needle moves towards the east, whether the opening of the disc is towards the north or towards the south.

18. If the inclination is towards N.E. and S.W., the motion of the needle is westerly.

Experiments 14 to 18 are perhaps the most interesting and important of the entire series. Exp. 14 represents the direction of the gravitation currents that tend to restore the equilibrium which is continually disturbed by the thermal radiation of the northern hemisphere, while Exp. 15 represents the like direction in the southern hemisphere, and all the experiments demonstrate that *in the daily magnetic fluctuations, the motion of that end of the needle which is nearest to the equator should follow, precisely as observation shows that it does follow, the direction of the sun's meridional influence.*

b. Axis in magnetic equator.

19. When the disc is in the meridian, the current-polarity and the magnetic polarity coincide.

20. If the disc is in the equator, with the opening to the east, when the top of the ring moves towards the north the needle declines to the east.

21. But when the motion of the ring is towards the south, the current polarity is reversed, and the needle declines to the west.

22. The reversal of the disc, placing the opening to the west, likewise reverses the polarity, the declination being east when the ring moves south, and west when the ring moves north.

23. The disc being inclined to N.W. and S.E., the needle declines towards the west (the action in Exp. 17 being reversed).

24. Changing the inclination of the disc to N.E. and S.W., the declination changes to east (reverse of Exp. 18).

From Exp. 19 to 24 we may infer that *in consequence of the action of the trade winds, combined with the greater radiation of the*

northern hemisphere, there should be a constant eastward tendency of the magnetic declination, such as is indicated by the secular variation of the needle.

c. Axis 45° from magnetic meridian.

25. When the disc is in or near the meridian, there is a slight tendency in the extremity of the needle which is under the opening of the disc, to follow the direction of the top of the ring. In all other positions the needle declines *from* the axis.

d. Axis variously inclined.

26. If the inclination of the axis to the meridian is less, or greater, than 45°, the results approximate respectively to those obtained when the axis is in the meridian, and when it is in the equator.

Art. XXXIII.—*Nitrates of Iron;* by John M. Ordway.

Of the scattered accounts to be met with respecting the action of nitric acid on iron, few or none are worthy of entire confidence, because all are defective in the statement of conditions; and failing to make due reservations, they commonly set forth partial facts for general truths. In this way Thenard long ago fell short of correctness in each and every assertion when he said,[1] "On ne peut obtenir que du nitrate de fer vert et du nitrate de fer rouge; et encore le premier ne se forme-t-il qu'en prenant de l'acide à 5°, et le second, qu'en employant de l'acide au plus à 12° à 15°. Si l'acide étoit plus concentrée, une portion de l'oxide rouge se precipiteroit, et l'on n'en retrouveroit plus en dissolution que trés peu s'il avoit 36° à 40°." And some later observers have been little more successful in generalizing from insufficient data. It is singular that chemical writers in speaking of the varied reactions have hardly alluded to any other cause of the great diversities observed except difference in the strength of the acid used. Davy does indeed go so far as to make a rather indefinite mention of temperature, and describes the phenomena thus:[2] "When very dilute nitric acid, that is, such as of specific gravity 1·16,[3] is made to oxydate iron without the assistance of heat, the solution gives out no gas for some time, and becomes dark olive-brown."[4] "When very dilute nitric acids are made to act upon iron, by the assistance of heat, nitrous oxyd is produced in considerable quantity mingled with

[1] Annales de Chimie, lvi, 75. [2] Collected Works of Sir H. Davy, iii, 112.

[3] The 1·16 must be a misprint, for an acid of that strength can hardly be called "very dilute," and in fact nitric acid of sp. gr. 1·16,—except at very low temperatures,—acts rapidly on iron of any kind, and evolves gas abundantly.

[4] Collected Works, iii, 130.

nitrous gas and nitrogen." "In the beginning of a dissolution the nitrous gas generally predominates, in the middle nitrous oxyd, and at the end nitrogen."

It should be remembered that the terms *iron* and *nitric acid* are too generic to allow qualifiers and definers to be altogether dispensed with. It must also be borne in mind that a finely divided metal does not always behave exactly like compact lumps of the same; and that heating or cooling a few degrees sometimes suffices to change the order of affinities of substances in mutual contact. A sound philosophy would therefore at the outset suggest the inquiry whether the action of nitric acid on iron is not a function of several variables, such as the quality, the quantity, and the strength of the acid; the form, the kind, the state, and the amount of iron, and the quantity put in at a time; the initial temperature, and the range of temperature allowed during the action, pressure, light, rest or agitation, and the access or exclusion of air.

Having only the data afforded by a few hundred experiments, I cannot presume to enter into a systematic and thorough discussion of all possible causes of variation; but the narration of some of the principal trials will serve to show that most of these supposed influences are really operative.

Wrought iron turnings and weak acid were found sometimes to give off hydrogen copiously and produce a green protonitrate, while in other instances nitric oxyd was evolved and a red pernitrate was formed.

For some comparable trials, turnings were secured clean and all alike by catching them as they fell from the lathe in turning a shaft of common rolled iron. The acid used was a nearly colorless commercial nitric acid about free from chlorine and sulphuric acid. The following are the final approximating terms of convergent series of experiments made by varying the temperatures, all other things being equal:

1, *N.*—At 45° C., 100 g. of nitric acid of sp. gr. 1·03, with 5 g. of iron added all at once, gave off hydrogen continuously. The temperature during the action rose to 49°.

n.—At 46° C., the same materials gave hydrogen for a few moments and then, changing, extricated nitric oxyd to the end. The temperature rose to 50°.

2, *N.*—At 35° C., 100 g. of nitric acid of sp. gr. 1·04, and 5 g. of iron yielded hydrogen only and made a protonitrate. The heat rose to 45½°.

n.—At 36° C., the same quantities of the same materials gave nitric oxyd and produced a dark red solution.

3, *N.*—At 31° C., 100 g. of acid of sp. gr. 1·05 and 6 g. of iron gave off hydrogen only. The thermometer inserted rose to 47½°.

n.—At 32° C., 100 g. of acid 1·05 and 6 g. of turnings evolved nitric oxyd and heated to 47° C.

4, *N.*—At 16° C., 5 0g. of acid of sp. gr. 1·06 with 3 g. of iron evolved hydrogen throughout the action, though the temperature rose to 27°.

n.—At 17° C., 50 g. of acid and 3 g. of turnings gave off hydrogen for a moment, then stopped entirely, and then went on and evolved nitric oxyd to the end.

5, *N.*—Taking another kind of iron turnings, at 29° C. 60 g. of nitric acid of sp. gr. 1·04 and 3 g. of iron gave hydrogen and a protonitrate.

n.—At 30° C., the same quantities of the same materials gave hydrogen for a while, and then changing evolved nitric oxyd and made a pernitrate.

It is worthy of notice in these cases that the final action is determined by the initial temperature, and not by that which may be reached during the operation. We see too that when the temperature alone is varied, the dividing limit between entirely different reactions is pretty sharply defined; but with unlike qualities of iron, the limit is by no means the same for the same strength of acid. Indeed, in trying some sorts of the metal, there has been no production of hydrogen observed under any circumstances. And it may be that the failure of others to notice such a phenomenon is owing mainly to their chancing to operate with iron of the purer kinds. Priestley[8] reports having once obtained "explosive air" by warming iron with nitrate of iron; and this solitary instance appears to be the only one on record.

The essential peculiarity of hydrogen evolving iron remained a mystery till I noticed that the gas blackened particles of rust floating in the water over which it was caught. The gas was found to be capable of discoloring paper moistened with a lead solution. So a small fractional per-centage of sulphur is the chief, if not the only, constituent of iron which suffices to make the acid depart from its more usual modes of operation; and probably it is the proportion of sulphur which determines for acid of a given strength the dividing limit of temperature between hydrogen and nitric oxyd production. I have seen a temporary evolution of hydrogen even with an acid of sp. gr. 1·08, and it is possible that a still stronger acid might operate in the same way on some irons, at a very low temperature.

The following trials show differences caused by what is conveniently designated as "mass;" but how far "mass" depends on mere weight and how far on the extent of surface exposed to action has not been ascertained.

6, *a.*—At 35° C., 100 parts of nitric acid of sp. gr. 1·04, with 5 parts of wrought iron turnings, gave off hydrogen only.

b.—At 35° C., 100 parts of nitric acid of sp. gr. 1·04, with two parts of iron turnings, gave hydrogen at first and then evolved nitric oxyd and made a red solution.

7, *a.*—At 23° C., 100 parts of nitric acid of sp. gr. 1·04, with 28 parts of cast iron, gave hydrogen only and made a protonitrate.

[8] Experiments and Observations on Different Kinds of Air; London, 1779, iii, 134.

b.—At 23° C., 100 parts of nitric acid of sp. gr. 1·04, with 4 parts of the same cast iron, evolved nitric oxyd and yielded a pernitrate.

8, *a.*—100 parts of nitric acid of sp. gr. 1·05, with 50 parts of cast iron, emitted hydrogen only.

b.—100 parts of nitric acid of sp. gr. 1·05, with ten parts of the same iron, extricated hydrogen at first and then evolved nitric oxyd and produced a pernitrate.

Minute proportions of sulphur or phosphorus are known to have a wonderful effect on the physical properties of iron, and now the hydrogen production shows that one substance at least possesses a not less remarkable power of altering the normal chemical reactions; for when we take the purest iron to be had, such for instance as that used for fine wire, the alternative of nitric oxyd evolution is silent solution. When no gas is set free the product may be either protonitrate, or pernitrate, or an uncertain mixture of the two; and after long continued action, protoxyd of iron or peroxyd may be precipitated. Oftentimes, when air is freely admitted there is not only no loss but an actual gain in weight. In such cases probably nitric oxyd in fact forms slowly, but rising no farther than the surface of the liquid it is regenerated and fixed by atmospheric oxygen. There is always a production of nitrate of ammonia, but I have invariably found the quantity much too small to account for all the oxydation that takes place.

For trials of the purer irons, coarse wire was taken, of such size that one meter weighed 15·6 g. A fine wire was used weighing 0·54 g. per meter, and therefore for the same weight presenting 5⅓ times as much surface as the course.

9, *a.*—At 0° C., 100 g. of nitric acid, of sp. gr. 1·05, with 5·2 g. of coarse wire, gave off very little gas and made a protonitrate containing 0·26 p. c. of ammonia.

b.—At 22° C., 105 g. of nitric acid of sp. gr. 105, with 5·2 g. of coarse wire, gave off nitric oxyd, and made a solution of basic pernitrate which contained 0·12 p. c. of ammonia.

10.—At 0° C., 54 g. of perfectly pure nitric acid of sp. gr. 1·05 with 6 g. of fine wire, lost 0·080 g. and made a protonitrate and some green oxyd. The product contained 0·2 p. c. of ammonia.

11.—At 0° C., 68 g. of nitric acid of sp. gr. 1·06 and 3·5 g. of fine wire lost only 0·090 g. Somewhat more than half of the iron dissolved was in the state of protonitrate. There were in the product 0·09 p. c. of ammonia.

12.—At 0° C., 97 g. of nitric acid of sp. gr. 1·10 and 10 g. of fine wire lost 0·72 g. The product contained 0·26 p. c. of ammonia and 6·7 p. c. of iron, of which about two-thirds were in the form of protonitrate.

Thus, by operating on the purer sorts of iron at low temperatures, we may get an unmixed protonitrate, with acid of as high a specific gravity as 1·05. And acid of much greater strength gives some protonitrate, if the action is retarded by cold.

13.—71 g. of nitric acid of sp. gr. 1·25 being cooled in snow, 10 g. of the fine wire were gradually added. 8 g. of the iron were dissolved and the loss was only 1·23 g. Were the metal in this case oxydized by the mere decomposition of the acid, 4 g. of nitric oxyd should have been given off. The solution did indeed contain some ammonia, but its amount was too trifling to account for any considerable part of the oxydation.

The nitric oxyd, therefore, instead of passing off as fast as it was liberated, must have been in part oxydized by the superincumbent air and absorbed back into the liquor. The following instance gives a more forcible illustration of this matter:

14.—7 g. of fine wire were gradually dropped into 97 g. of nitric acid of sp. gr. 1·20. The iron was all taken up leaving only some black skeletons of the fibers. There was no loss, but a gain of 0·26 g. The product contained 0·13 p. c. of ammonia and a trace of protonitrate.

As the iron in this experiment was all used up, it is plain that the production of ammonia and a protosalt was not owing to the after reaction of the partly made pernitrate on an excess of the metal. And it seems likely that the formation of protonitrate, pernitrate, nitrate of ammonia, and nitric oxyd, and the absorption of oxygen from the air were going on simultaneously, and during the whole time.

It is not certainly known whether, in the direct action of nitric acid on iron, the generation of ammonia and the formation of protonitrate have any necessary connection. I have never detected protonitrate in the product unless ammonia was also present; but ammonia is sometimes found when the iron is all in the state of pernitrate. Yet in the latter case a protosalt may have been formed in some stage of the operation and subsequently oxydized as the action went on. No doubt there is often a partial rearrangement of the elements; for a perfectly clear solution decanted from the undissolved iron, will sometimes in the course of a few days, deposit a considerable quantity of rust and give off some nitric oxyd.

The inquiry naturally suggests itself whether in case of silent solution there may not be a nitrite formed,—2Fe and $3NO_5$ giving $Fe_2O_3\,3NO_4$. Were it so the product would slowly decolorize permanganic acid; but the amount of permanganate bleached by any of the products has never much exceeded what was due to the quantity of protonitrate present. I have not, indeed, found any good reason for believing that there is any such thing as a sesquinitrite of iron.

When we bring together iron and nitric acid of as high a specific gravity as 1·3 the phenomena of passivity sometimes manifests itself; and the induction of such a state depends not merely on the strength of the acid, but has some relation to its quality and temperature, and to the kind and condition of the

iron. In speculations respecting the cause of passivity, it has not unfrequently been taken for granted that this singular change is wrought in iron only by the very strongest acid. Thus in a brochure[6] setting forth a new theory of the constitution of acids, Peretti gives the following unsound instance in support of his views, and goes on to argue that inactivity is owing to the lack of a certain hypothetical deutoxyd of hydrogen:—"Il ferro che è attaccato si fortemente da questo acido, preparato con il commune metodo AzO_2+2HO_2, cessa di esserlo posto a contatto con l'acido azotico fumante AzO_4+HO_2 cioè a dire con questo acido privato de un equivalente di acqua," etc. But the fact that an acid of as low a specific gravity as 1·20 may refuse to act on certain kinds of iron is far from lending any support to this and some other theories that have been proposed. The strongest acid has apparently no more effect on iron than so much water would have; but with acid moderately strong there is often a momentary action, and then the metal brightens and undergoes no further change. Initial temperature has much to do with determining the continuance or termination of the active state; and yet for any particular acid or iron it is not easy to state the exact degree beyond which quiescence is no longer possible; for in a still liquid, an incipient action may, by reason of local heating, get such a start that it will go on to the end, while a thorough and constant stirring would so distribute the small amount of heat evolved on first contact as to cause a speedy cessation of chemical change. But when passivity has once supervened, it requires very strong heating of the acid to make it attack the iron again. The following trials show that in treating of passivity we should take into account not only the strength of the acid but also its quality and temperature, the degree of agitation, and the kind and condition of the iron:

15.—Some nearly pure commercial nitric acid of sp. gr. 1·36 being heated to 34° C. and briskly stirred, a bit of bright iron wire was dropped in. The action continued till the metal was all gone.

In another experiment with the acid at 33° C., the action quickly ceased.

16.—Nitric acid of sp. gr. 1·38 warmed to 31° C., soon rendered iron wire passive.

Some of the same acid at 32° C., kept on acting till the iron was used up.

17, *a*.—A nearly pure and colorless acid of sp. gr. 1·39 warmed to 30° C., rendered iron wire passive; but when such acid was heated to 31° C., before adding the iron, the action kept on.

b.—Some crude red acid of sp. gr. 1·39 warmed to 41·5° C. exercised but a momentary action on wire; and when the acid and iron were heated together after the contact, the wire did not recover its active condition till the temperature was carried up to 88° C.

[6] Dell'Azione chimica dell'Acqua sopra i Sali e sopra gli Acidi. Roma, 1861.

This acid heated to 42° C. rapidly dissolved iron wire.

18, *a*.—A pale commercial acid of sp. gr. 1·40, warmed to 33° C., refused to dissolve iron wire.

With such acid at 34° C., the action kept on.

b.—Some pure acid redistilled with bichromate of potash, having the sp. gr. 1·40, and being warmed to 36° C., quickly induced passivity in iron wire.

With some of the same acid at 37° C., the action did not cease till the iron was all gone.

c.—Pure red acid of sp. gr. 1·40 warmed to 58° C., rendered wire passive.

Such acid at 59° C. continued to act.

d.—Some commercial red acid of sp. gr. 1·40 warmed to 65° C., had but a momentary effect on iron wire.

The same acid at 66° C., kept on acting.

19.—A pale acid of sp. gr. 1·41 heated to 41° C., rapidly dissolved iron dropped in during slight agitation; but with the initial temperature 40° C., the wire became passive.

When this same acid was briskly shaken at the time of contact, 49° C. was the limit of passivity.

20. *a*.—Pale acid of sp. gr. 1·42, at 55° C., rendered iron wire passive; at 56° C. the action kept on.

b.—Common red nitric acid of sp. gr. 1·42, even when warmed to 82° C., induced passivity in iron; but with the same acid at 83°, the action continued.

21.—Steel wire scoured bright became passive when it was agitated with pure colorless nitric acid of sp. gr. 1·30, heated to 50° C.; but when the acid had first been warmed to 51° there was a continued action.

Other acid of sp. gr. 1·30 with other sorts of steel, gave the same limit of passivity.

22, *a*.—Pure nitric acid of sp. gr. 1·34 heated to 71° C., soon ceased to act on steel wire; when such acid was first heated to 72° it did not induce passivity.

b.—The same acid even at 100° C., had no action on the same steel wire freshly annealed and scoured bright.

For trials of rough and less compact steel, two very long turnings were broken up, and furnished bits enough for a large number of experiments with metal of one and the same quality.

23.—On this steel nitric acid of sp. gr. 1·26 acted rapidly and continuously, even when it had been previously cooled to 0° C.

Nitric acid of sp. gr. 1·27 and at 40° C. soon ceased to act on a bit of steel added during brisk agitation; with the acid first heated to 40·5° the action continued.

And with acids of sp. gr. 1·28, 1·29, 1·32, 1·33 and 1·34, the limit of passivity was between 35° and 40° C.

With acid of sp. gr. 1·345 and at 52·8° C., the steel became passive; with the same acid first heated to 53·3°, the action went on.

Acid of sp. gr. 1·348 even at 76·7° C. rendered the steel passive; when this acid was first heated to 79·5° the action would not stop.

24.—The steel turnings were also tried with common red nitric acid.

Such acid of sp. gr. 1·34, at 65° C., rendered the steel passive; with the initial temperature 65·6° it continued to act.

Acid of sp. gr. 1·335, at 58·3° C., soon ceased to act; with such acid at 58·9° the action went on to the end.

With acid of sp. gr. 1·33, at 49·4° C., the action was momentary; with this acid first heated to 50° there was no stoppage.

With acid of sp. gr. 1·327 the limit of passivity lay between 47·2° and 47·8° C.

Acid of sp. gr. 1·32 at 32·2° induced passivity; with the same acid at 32·8° the action continued.

With cast iron the limit of passivity cannot be so precisely defined. Acid of moderate strength often continues to dissolve the iron very slowly and silently after the first momentary, violent action is over. It having been found by many trials that passivity may occur in cast iron even with acid of as low sp. gr. as 1·20, the following definite experiments were made:

25.—Took in each case a tared lump of iron weighing between 2·8 and 3·3 grams, and some acid at 25·5° C. At the end of four hours the bits of iron were cleared of the loosened carbon, washed, dried and weighed.

With acid of sp. gr.		1·20	the iron had lost		0·218 g.
"	"	1·19	"	"	0·290
"	"	1·18	"	"	0·386
"	"	1·17	"	"	1·497
"	"	1·16	"	"	1·529
"	"	1·15	"	"	1·512
"	"	1·14	"	"	1·454

With the 1·20 acid the apparent action lasted but five minutes, and in the next two cases the evolution of gas continued somewhat longer. In the remaining instances the action lasted throughout.

26.—Of another specimen of iron, pieces weighing between 6 and 7 grams were tried, each with 20 c. c. of acid at 28° C. At the end of 13 hours the products were gelatinous, basic pernitrates, turbid looking, but quite soluble in water.

With acid of sp. gr.		1·18	the iron had lost		2·264 g.
"	"	1·175	"	"	2·295
"	"	1·17	"	"	2·266
"	"	1·16	"	"	2·246
"	"	1·15	"	"	2·141

27.—Another sample of cast iron in pieces weighing between 2·7 and 3 grams was tried in each instance with 20 c. c. of acid at 23° C. At the end of nine hours the iron in acid of sp. gr. 1·20 had lost 0·285 g.

"	"	1·195	"	0·296
"	"	1·19	"	0·279
"	"	1·185	"	0·315
"	"	1·18	"	0·375
"	"	1·175	"	0·407
"	"	1·17	"	0·414
"	"	1·165	"	0·708
"	"	1·16	"	1·692
"	"	1·155	"	1·856
"	"	1·15	"	1·830

In the first instance the action was apparently over in six minutes. In the next five cases all was quiet at the end of about twenty minutes. In the last three there was no stoppage.

The phenomenon of passivity,—which had been observed by Wenzel[7] as long ago as 1782, and has been the subject of more speculation than experiment,—is explained by some as owing to the formation of a coating of insoluble oxyd. But we have no reason to suppose that an uncombined oxyd can possibly be formed in the presence of a great excess of strong acid. In fact after contact with the acid the surface of the iron often remains as bright as ever, and a crust so thin as to be transparent must be too thin to be impermeable.

Others make the more plausible assertion that the metal immediately becomes covered with a layer of nitrate insoluble in nitric acid. Thus Heldt says:[8]—"Die Haut von saltpetersauren Eisenoxyd durch welche das blanke Metall mit seinem Glasz hindurch schimmert, ist unter einer guten Lupe deutlich zu erkennen." I have never been able to detect any such film with a magnifier, and my experiments with heated nitric acid go to show that in many cases an adhering coat of nitrate cannot exist; for though the crystallized salt is not soluble in cold strong acid, it dissolves readily enough even in monohydrated acid with the aid of a moderate heat. When iron has become passive while cold, the acid ought not to require heating beyond 50° to make the action recommence. But we have seen that even boiling sometimes fails to remove passivity.

When the iron is temporarily attacked, an incrustation of oxyd, or of nitrate, could only by degrees acquire sufficient thickness to resist the acid; and hence the theory of a protective film would require the gradual cessation of activity; but in fact the cessation is usually sudden and abrupt.

Reason seems to be on the side of those who refer passivity to a molecular change in the iron, which may be induced by a momentary electric action set up on the first contact of the acid with the metal. And such an alteration in the electric or chemical relations of iron is no more wonderful than the modification of the mechanical properties of steel by tempering, or the induction of permanent magnetism in steel.

The following summary shows the results to be obtained by bringing together iron and nitric acid under various conditions.

1.—There may be either no perceptible action or only a momentary one, the iron quickly becoming passive.

Passivity supervenes most readily with a red acid and with carburetted iron. And steel has its liability to become inert enhanced by annealing.

[7] Lehre von Verwandschaft der Körper, p. 108; note.
[8] Erdmann's Jour. f. Pr. Chem. xc, 267.

2.—There may be silent action with the production of protonitrate, or of pernitrate, or of both together.

3.—There may be a more or less rapid evolution of gas,—mostly nitric oxyd,—and the formation of an acid, normal, basic, or rusty pernitrate, or of a mixture of protonitrate and pernitrate.

4.—Hydrogen may be given off continuously, while a protonitrate is formed.

5.—Hydrogen may be evolved rapidly at first and then more and more slowly till there comes a pause; after which the reaction changes and nitric oxyd is liberated abundantly, a pernitrate being the final product.

6.—A very small portion of the acid may be decomposed so as to generate nitrate of ammonia; and this can take place while nitric oxyd, or hydrogen, or no gas at all is given off.

7.—During a moderate action there may be an absorption of oxygen from the air, and consequently a greater amount of oxydation will ensue than can be accounted for by the gases extricated and the nitrate of ammonia formed.

Pernitrate solutions made with weak acid and excess of iron are generally so basic as to become turbid when they are treated with a solution of any sulphate. The precipitate, which is probably the tribasic persulphate of iron, is producible whenever the nitrate solution contains less than two equivalents of acid to one of ferric oxyd.

The proneness of nitric acid to dissolve an excess of iron, renders it hardly possible to make directly a solution that shall contain an exact normal nitrate; for even if we try to use the precise quantities of material which theory would indicate, the reaction is not simple enough to allow us to predict just how much acid will be consumed in effecting the oxydation. Yet the procuring of a normal nitrate, which has been spoken of by some writers as very difficult, is far from being a hard matter. We have only to resort to the process by which most other crystallizable salts are insured free from excess of acid or base. The nitrate readily crystallizes out of an acid or normal solution, and of all the ferric salts it is the easiest to obtain in crystals and in a state of purity. In concentrating a solution, care should be taken to apply but a moderate heat; and, before setting it aside to crystallize, enough strong nitric acid should be added to make the liquid seen in a thin stratum appear of a pale yellow color instead of a deep red.

Solid Nitrate of Iron.—There are two definitely crystallized sesquinitrates of iron, differing much in form and composition. The cubic nitrate noticed by Schönbein[9] in 1836 and analyzed by Hausmann[10] in 1854, is a tetrahydrate, $Fe_2O_3\,3NO_5\,12HO$,

[9] Pogg. Ann., xxxix, 141. [10] Annalen der Ch. and Ph., lxxxix, 109.

—and, as will be shown presently, is produced only under circumstances of peculiar constraint. The more commonly occurring salt, which forms when there is no deficiency of water, is the oblique rhombic sexhydrate,—$Fe_2O_3\ 3NO_5\ 18HO$,—described in this Journal in 1850.[11] At that time I was not aware that any previous analysis had been recorded; but in a little work published in 1834, entitled "Manuel du Fabricant d'Indiennes, par L. J. S. Thillaye," is to be found the following passage:—"Si l'on veut obtenir des cristaux de pernitrate, on fait dissoudre lentement le fer dans l'acide nitrique à 34°, en plaçant le vase dans un lieu frais. Lorsque la dissolution est à peu près complète, il se forme des cristaux qui affectent la forme de prismes droites à quatre pans et à bases carrées, quelquefois ils ont six pans. * * * * Le pernitrate cristallise est formé de Acide Nitrique 41,968, Peroxide de fer 20,725, Eau 37,307." This composition corresponds nearly to $Fe_2O_3 . 3NO_5 . 16HO$, and the specimen analyzed must have been a mixture of the two sorts. Having observed scores of crops of crystals formed under very diverse circumstances, and having invariably found the sexhydrated salt to belong to the monoclinic system, I think it would not be too much to say that those who speak of square prisms, either have had the cubic nitrate or a mixture to deal with, or have used Vauquelin's eyes instead of their own. "An observation which Citizen Vauquelin has communicated" is thus given in Fourcroy's Chemistry:—"Concentrated nitric acid poured on an oxide of iron arising from the decomposition of water, had been left in contact with it several months. * * * Citizen Vauquelin was much astonished on stirring the liquor, which was of a brown color, to see in it several large crystals, the least of which weighed upwards of four grammes. * * * Their form was that of a square prism terminated by a bevel." As Vauquelin used concentrated acid, he might possibly have had the cubic crystals; but the cubic nitrate is not often modified, and the last clause, respecting termination "by a bevel," suggests a query whether the dimetric form was not predicated from a hasty glance rather than from measurement or from careful inspection. And there is the more room for a doubt because in "Citizen" Vauquelin's time the science of crystallography lacked much of the simplicity and precision which it has subsequently attained. In all likelihood it was the oblique nitrate which was first observed by Vauquelin; and I may, perhaps, rightfully claim to have been the first to determine its true char-

[11] The editor of the Chemical Gazette,—xii, 211,—speaking of Hausmann's nitrate says:—"Ordway gave the formula $Fe_2O_3\ 3NO_5\ 18HO$ for it." He should have observed that I gave no formula for the still undiscovered cubic salt, but described crystals the inclination of whose upright prismatic faces differed 11° from a right angle.

acter and composition, and its close correspondence to the nitrates of alumina and chromium.

Hausmann obtained the cubic nitrate by evaporating a solution, at a very moderate heat, to the consistency of syrup, and then adding to it half its volume of nitric acid. By analysis, the crystals pressed in absorbent paper, gave him per-centages corresponding to $Fe_2O_3, 3\frac{2}{9}NO_5 + 13HO$, equal to $Fe_2O_3, 3NO_5, 12HO + \frac{2}{9}(NO_5 4HO)$.

Wildenstein[13] found several pounds of cubic crystals deposited from a quantity of very strong commercial nitrate that had stood a year and a half. They had almost exactly the composition $Fe_2O_3, 3NO_5, 12HO$. These accidentally formed crystals appear to have come from a somewhat basic liquor deficient in water; and that the segregation had taken place under very unfavorable circumstances, is shown by the fact that only "10 Pfund" crystallized out of "$2\frac{1}{2}$ Centner" of the solution.

Hausmann's crystals were produced in a very concentrated liquor containing a large excess of acid,—a condition much better suited to giving a large crop. A lack of water is, no doubt, the essential requisite for the production of cubic nitrate; for I find, by many experiments, that unmixed cubic crystals can be made at pleasure by so adjusting the solution to be crystallized, that the attraction of the tetrahydrated nitrate for water, shall be rather more than counteracted by the attraction of an excess of nitric acid for water;—that is, so that the liquid shall consist of tetrahydrated ferric nitrate dissolved in trihydrated nitric acid. Almost the whole of the nitrate then crystallizes out, because at low temperatures it is but slightly soluble in acid of such strength. A solution containing more water than will make up $Fe_2O_3, 3NO_5, 12HO + n(NO_5, 3HO)$ may afford a few of the rhombic sexhydrate crystals mixed with the cubic; and one containing less water will hardly give any solid nitrate at all. When there is water enough present to make up $Fe_2O_3, 3NO_5\ 18HO + n(NO_5, 4HO)$, the crystals will be all oblique rhombic.

The conditions of formation of the solid nitrates are somewhat similar to those for the production of the two hydrated chlorids. When a solution is not basic and contains between six and twelve equivalents of water to one of perchlorid of iron, it first deposits the deutohydrate, $Fe_2Cl_3\ 6HO$, in transparent crystals, and then goes on to form the light yellow, opaque, indistinct tetrahydrate, $Fe_2Cl_3\ 12HO$. Unless the liquid lacks water, no transparent crystals can make their appearance.

For making cubic nitrate, the oblique crystals afford a definite material that admits of appreciable treatment. We may take a weighed quantity of these crystals in a tared dish, and evaporate by a gentle heat about fourteen per cent of their weight, or six

[13] Erdmann's J. für Pr. Ch., lxxxiv, 243.

equivalents of water; then add trihydrated nitric acid enough to double the bulk of the liquid, and set the whole aside to crystallize. A still easier method is to melt one equivalent of the common nitrate and add a little over two equivalents of monohydrated nitric acid. Atmospheric moisture must be carefully excluded during the cooling and the subsequent repose.

The following experiment was made with a view of finding out whether there is any crystallizable nitrate of iron containing still less water than the cubic salt:

28.—100 g. of $Fe_2O_3, 3NO_5, 18HO$, were gently heated till 27 p. c. were evaporated, one-half of the water and one-eighth of the acid being expelled. 42 g. of monohydrated nitric acid were added and the dish suitably covered was set out in an open shed for several days in the coldest weather of winter. No crystals formed except a slight fringe around the edge, where a little moisture had probably been absorbed from the air.

Afterwards the whole was heated and 33 g. of oblique rhombic crystals were dissolved in it. On standing in a cold place a full crop of the cubic salt was soon deposited.

So then the drying power of nitric acid does not enable us to get a nitrate containing less water than the tetrahydrate, but, when pushed too far altogether prevents crystallization. Yet Scheurer-Kestner[13] speaks of a salt of the very remarkable and irregular composition $Fe_2O_3, 3NO_5, 2HO$. To obtain this, he evaporated a solution of nitrate, at a moderate heat, till it became very dense and a part was decomposed. The liquid portion on cooling produced a mass of confused crystals of the almost anhydrous salt. The mother liquor by long standing gave crystals of the cubic nitrate.

M. Scheurer-Kestner erroneously cites me as having mentioned in this Journal, vol. xxvii, p. 197, such a salt as $Fe_2O_3, 3NO_5, 6HO$. He probably meant to refer to p. 17 of that volume, where I have taken the liberty of showing the generic agreement of the sesquinitrates with the sexhydrated protonitrates, by writing the ferric salt $\dot{F}e+3\dot{N}H_6$; and he must have been led astray by a misapprehension of the Berzelian method of notation. A dihydrated nitrate would be too singular to be accepted without a full characterization; and I should be very far from calling on the world to believe in a $\dot{F}e\dot{N}_3H_6$ on the strength of a mere formula. At the time of writing the article on nitrates, I had not met with Hausmann's account of the cubic salt, and therefore was not aware of the peculiarity of nitrate of iron in ranking among the tetrahydrates as well as in the more extensive class of sexhydrates. Other salts of the tetrahydrate class may exist as anhydrous nitrates, and it is a question whether Scheurer-Kestner's more recently discovered salt, $\dot{F}e\dot{N}_3H_2$, is not

[13] Bulletin Soc. Chimique de Paris, March, 1862, p. 36.

in reality the anhydrous pernitrate of iron with a slight admixture of the cubic nitrate. For he did not obtain it in well defined crystals and therefore could not be sure of its singleness; and moreover there is no analogy in favor of the formula which his analysis assigns to it. It is very remarkable that the tetrahydrate is more fusible than the oblique rhombic salt which contains nine per cent more water. The sexhydrate melts at 47° C., and Hausmann found the cubic nitrate to liquefy at 35° C.; but his product contained a little free acid and it is probable that the pure tetrahydrate melts at a point between 35° and 40°.

If six equivalents of water are added to the melted cubic nitrate, heat is evolved, and, after a while, the whole becomes solid.

The unaccountable anomaly of greater fusibility with a less percentage of water is not peculiar to the nitrates of iron, but is shown also by the perchlorids. For I find the transparent dihydrate, $Fe_2 Cl_3$ 6HO, to melt at 31° C., while the opaque tetrahydrate, $Fe_2 Cl_3$ 12HO, fuses at 35 5° C. And if a mixture of the two chlorids is slowly heated, the transparent crystals liquefy first. The addition of six equivalents of water to the melted dihydrate is attended with the production of heat.

The plan of using fuming nitric acid to contend with a hydrated nitrate for the possession of water, of course admits of more extended application. With nitrate of alumina indeed it does not work well, on account of the high melting point of that salt and its very slight solubility in even boiling acid. Nitrate of chromium is more tractable, and a mixture of monohydrated acid with the melted crystals, on standing, lets fall nearly all the nitrate as a confused crystalline mass probably containing less than twelve equivalents of water, and having little resemblance to the cubic nitrate of iron. In a single instance I have seen in the mass one or two crystals apparently cubic, but they were too minute and scanty to allow any special examination. Nitrate of glucina has never been obtained except as a trihydrate, as mentioned in a former paper. Since the date of that publication I have succeeded in getting more distinctly formed crystals which appeared to the eye dimetric, being indeed very short square octahedra. It remains then still uncertain whether the other sesquinitrates can form salts corresponding to the cubic nitrate of iron.

With the help of strong nitric acid, the nitrates of manganese and zinc may be crystallized with less than six equivalents of water, but these products have not yet been fully examined.

Protonitrate of iron is a salt of such a nature that we can never expect to get it in the solid state except as a sexhydrate.

Protonitrate of Iron.—The most convenient way of procuring

ferrous nitrate, is to dissolve the protosulphid of iron in nitric acid of less sp. gr. than 1·12, no considerable elevation of temperature being allowed. Though protonitrate crystals are very unstable, a moderately strong solution may be evaporated without much risk by a heat not exceeding 60° C. As the strength increases, however, the temperature must be lowered, especially if there is an excess of acid. By thus proceeding with greater caution as the liquid becomes more concentrated, we may get it strong enough to crystallize when exposed to the cold of winter.

The following experiments show the difference between weak and strong, acid and neutral solutions, in respect to their endurance of heat:

29, *a*.—A solution made directly with sulphid of iron and nitric acid of sp. gr. 1·08, contained 29 p. c. of $FeO, NO_5, 6HO$, and 0·6 p. c. of free acid. Some of it heated slowly remained clear and unchanged while the temperature rose to 83° C. At 90° it underwent a rapid transformation and became rusty.

b.—Some of the solution mixed with about its own weight of water, continued unaltered till it was heated to 100° C. It required some five minutes boiling to effect a complete rearrangement of its elements.

c.—Some of the solution on being merely mixed with one-sixth of its weight of pure nitric acid of sp. gr. 1·42, at once gave off gas and made a clear, dark red liquid.

d.—Some of the solution was mixed with nearly its own weight of nitric acid of sp. gr. 1·10 and heated slowly. At 66° C., it started and quickly changed to pernitrate.

e.—A mixture of 28 g. of the solution with 11 g. of pure nitric acid 1·10, began to alter at 77° C.

30.—A solution of the crystals, saturated at 15° C. and containing 71 p. c. of $FeO, NO_5, 6HO$, was heated in a water-bath. It began to give off gas at 85° C. At 88° the rearrangement went on violently and was soon finished.

The crystals themselves while still wet, may be kept in the cold without alteration; but when they are quite free from mother-liquor, they are apt to start suddenly, even at the common temperature of the air, and undergo a rapid transformation, a dark red, clear, basic pernitrate being produced. The composition of the pasty mass, in one instance, was found to be about $Fe\,N_{1\cdot2}$; in another it was $Fe\,N_{1\cdot7}$. These products are apparently soluble in water; but the liquor is slightly opaline when looked at, though it is clear when seen by transmitted light. The crystals themselves therefore change to a substance almost perfectly soluble in water, while solutions of the crystals, by spontaneous decomposition, become rusty, a portion of the peroxyd assuming the inert, insoluble state.

The foregoing experiments show that neutral solutions, even when very strong, will bear a pretty high temperature. Weak solutions may be brought for a moment to the boiling point without immediate injury. But acid solutions undergo a change

much more readily, and the greater the quantity of acid the less stable are they.

Crystals of protonitrate of iron, well drained and dried at a very low temperature, were found to yield by ignition 27·565 p. c. of ferric oxyd. The formula must therefore be FeO, NO_5, 6HO, which would correspond to 27·778 p. c. of peroxyd.

A solution saturated at 0° C., yielded a quantity of peroxyd equivalent to 66·3 p. c. of the crystals. So at 0° the salt is soluble in half its weight of water.

A solution saturated at 15° C., contained 71 p. c. of crystals. Its sp. gr. was 1·48.

A solution saturated at 25° C., contained 75 p. c. of crystals. Its sp. gr. was 1·50. At 25° C., then the crystals are soluble in one-third their weight of water.

The slight difference in strength between cold and warm solutions, as well as the instability of the solid salt, shows the inexpediciency of attempting to do anything with it except in the coldest weather.

ART. XXXIV.—*Some Indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan;* by Professor ALEXANDER WINCHELL.

THROUGHOUT the northern part of Lenawee and Hillsdale counties, the southern and eastern parts of Jackson, and the southern and western parts of Washtenaw county, are found numerous tabular, detached masses of limestone, sometimes cropping out on a hill side, like a ledge in place, and sometimes imbedded two or three feet in the sand and gravel at the summit. The position of these masses is generally nearly horizontal, though for the greater part slightly tilted in one direction or another. They sometimes present an extent of six, eight, or twelve feet square; and in occasional instances even more, so as to offer every appearance of an outcropping formation. In some cases many hundred bushels of lime have been burned from them before exhaustion. Underneath them we find the semi-stratified drift materials so characteristic of the general surface of the peninsula. At the bottom of the drift, which in some places is not over ten or twenty feet deep, we find the rocks of the Huron, or more frequently the Marshall group, in place. Many patches, nevertheless, occur as far north as the outcrops of the Carboniferous limestone, and create great confusion in tracing the latter formation unless the fossils are strictly attended to. Smaller fragments of the same limestone are still more abundant throughout the same limits; and, by their disintegration,

have imparted a highly calcareous element to the soil, even along the arenaceous belts. The percolation of meteoric waters, in turn, has given rise, in great abundance, to calcareous springs, and deposits of marl, tufa and travertin.

In the southwestern part of the peninsula, in the counties of Berrien, Van Buren and Ottawa, similar phenomena are again observed. The calcareous element of the soil is even more abundant; and large patches of sand have become firmly cemented, so as to present the consistency and appearance of ledges of sandstone. It really requires an extended series of observations to convince one's self that the region does not furnish considerable outcrops of a sandstone formation—especially as numerous blocks of undoubted Marshall sandstone occur upon the surface.

Some examples of these phenomena may be more definitely cited. On the S.W. ¼ S.E. ¼ sec. 13, Woodstock, Lenawee County, (221),[1] in the side of "Prospect Hill," limestone occurs in tabular masses six by twenty feet, and seven feet thick. An old lime-kiln stands near. Similar limestone occurs on the S.E. ¼ S.W. ¼ sec. 12, Woodstock (223) and S.W. ¼ S.E. ¼ sec. 1. From the latter locality several hundred bushels of lime have been burned. On sec. 3 of the same township, the Marshall sandstone is reached at the depth of 4 to 12 feet from the surface. On sec. 4 the sandstone is known to be over 75 feet thick; so that there can be no mistake in assuming it to be in place. On the N.E. ¼ N.W. ¼ sec. 6, Woodstock (230), is a large tabular mass 10 feet long and known to be over 6 feet broad. The dip is toward the east.

On the N.W. ¼ N.W. ¼, sec. 32, Columbia, Jackson county, (233) is a mass of limestone. Sixty rods north of here the sandrock is known to be within 20 feet of the surface, and has been penetrated 44 feet. On sec. 30 it has been penetrated 60 feet. On the N.W. ¼ N.W. ¼ sec. 26, Liberty, Jackson county, (235), masses of limestone are so abundant that a kiln has been constructed and several hundred bushels of lime manufactured. At the time of my visit, about 35 cords of wood were piled by the kiln, indicating considerable confidence in the resources of the quarry. Fragments of Marshall sandstone, with its fossils, are abundant, mingled with the fragments of limestone. Similar masses of limestone may be seen again on N.W. ¼ N.E. ¼ sec. 26, Hanover, (239), and on the S.W. ¼ N.E. ¼ same section, (240). Several wagon loads of fragments have been removed from the subsoil over the principal mass at the latter place. On the S.E. ¼ S.E. ¼, same section, a common well reached the Marshall sandstone at the depth of 35 feet, and was excavated 40 feet in the rock. The hills on N.E. ¼ N.E. ¼ sec. 33, same township,

[1] These numbers designate the localities.

(243), are filled with fragments of limestone, while the Marshall sandstone is struck at the depth of 50 feet on sec. 35, and at 30 feet on sec. 27. Farther north, on secs. 10 and 11, Leoni, (92 and 206), similar fragments again occur. Also on sec. 25, Grass Lake, (208). At a place one mile northeast of Franciscoville, (209), 20,000 bushels of lime have been manufactured in ten or twelve years.

In the adjoining parts of Washtenaw county, several kilns proclaim the presence of extensive nests of limestone. Even within the corporate limits of the city of Ann Arbor an extensive deposit has been quarried; and just beyond the limits, on the east, are the ruins of a limekiln which, many years ago, exhausted still another deposit.

Similar masses of limestone occur in Hillsdale county, one half mile southwest of Jonesville, (270); on S.W. $\frac{1}{4}$ N.W. $\frac{1}{4}$ sec. 21, Allen, (274); N.E. $\frac{1}{4}$ N.W. $\frac{1}{4}$ sec. 21, Adams, (289); S.E. $\frac{1}{4}$ N.E. $\frac{1}{4}$ sec. 22, Adams, (291); N.E. $\frac{1}{4}$ N.E. $\frac{1}{4}$ sec. 24, Adams, (292); S.W. $\frac{1}{4}$ N.W. $\frac{1}{4}$ sec. 19, Woodbridge, (296), and in many other localities.

In the southwestern part of the state, on the S.E. $\frac{1}{4}$ N.W. $\frac{1}{4}$ sec. 11, Hartford, Van Buren county, (415), limestone is found within two feet of the surface over the space of three or four square rods. One hundred rods north of here the wells are from 40 to 100 feet deep, without reaching any native rock—though thick beds of cemented sand and gravel are frequently encountered.

On the S.W. $\frac{1}{4}$ sec. 17, T. 7 N.R. 13 W, Ottawa county, (438) is the last occurrence that will be cited. Several slabs 3 or 4 feet long have been removed, and others remain, over an area of at least a square rod.

It is quite evident that such masses of stratified limestone have not been rolled to the same extent as the quartzose and gneissoid boulders which constitute the most striking feature of the "northern drift" of the same regions. By some agency these tables have been lifted gently from their original sites and carefully deposited where we find them. Paying no regard to their included fossil remains, it might be imagined that they constitute the ruins of the Carboniferous limestone formation, whose place is between these fragments and the centre of the peninsula. This formation gently rises toward the periphery of the peninsula, and at certain distances from its present outcrops would intersect the highest diluvial hills in the places occupied by the fragments which I have described; and which, for this reason, might be imagined as marking the outermost limits of a once continuous formation of Carboniferous limestone. The abundant fossil remains contained in these fragments, however,

not to speak of their lithological characters, convince us that the rock belongs to a much earlier epoch.

In short, no doubt could be entertained by one who has examined the subject, that these fragments appertain to the age of the Corniferous limestone. The rock, in structure, is irregular, often brecciated, with streaks and nests of bituminous and argillaceous matter. At other times it is compact and massive. Not unfrequently it presents the peculiar structure known as "lignilites." All these characters belong to the Corniferous limestone as exposed along the western shore of Lake Erie, and at numerous points throughout the county of Monroe.

Turning to the more reliable evidence of the fossil remains, it may be stated that the following are examples of the more frequent identifications:

At 92, *Heliophyllum Canadense* Billings, *Clisiophyllum Oneidaënse* Bill., *Acervularia Davidsoni* E. & H., *Conocardium trigonale* Hall, *Proetus crassimarginatus* Hall, *Amplexus* and *Favosites.*

At 182, *Lucina proavia* Goldf., *Conocardium trigonale, Dentalium* and *Fenestella.*

At 208, *Lucina proavia* and three species of Bryozoa.

At 230, *Strophomena rhomboidalis* Wahl, *Chonetes glabra* Hall, *Spirifera gregaria* Clapp, *Atrypa reticularis* Dal.

At 233, *Chonetes hemispherica* Hall, *Atrypa reticularis, Cyrtodonta* (*Vanuxemia*) *Tompkinsi* Bill, *Pleurotomaria rotunda,* Hall.

At 270, *Chonetes lineata* Hall, *Atrypa reticularis.*

At 289, *Chonetes lineata, C. glabra* Hall, *Atrypa reticularis, Leiorhynchus multicosta* Hall, *Rhynchonella Thalia* Bill., *Lucina proavia, Proetus crassimarginatas* Hall, *Platyceras and Proetus* sp.?

At 291, *Cyathophyllum Zenkeri* Bill, *Chonetes lineata, C. glabra, Orthis Vanuxemi* Hall, *Strophomena hemispherica, S. rhomboidalis, Spirifera varicosa* Hall, *S. gregaria, Atrypa reticularis, Charionella scitula* Bill., *Rhynchonella Thalia, Lucina proavia, Conocardium trigonale, Proetus crassimarginatus, Fenestella, Producta* (two species), *Streptorhynchus, Athyris, Platyceras.*

At 292, *Orthis Vanuxemi, O. propinqua* Hall.

At 296, *Chonetes glabra, C. arcuata* Hall, *Stricklandia elongata* Bill.

At 298, *Strophomena hemispherica.*

The following are the more common Corniferous fossils occurring in the Drift at Ann Arbor:

Favosites Gothlandica Goldf., *F. cervicornis* De Blainv., *F. turbinata* Bill., *F. polymorpha* Goldf., *F.* (*Emmonsia*) *hemispherica* Y. & S. sp., *Fistulipora Canadensis* Bill., *Michelinia convexa* D'Orb., *M. favosoidea* Bill., *Alveolites labiosa* Bill., *A. Rœmeri* Bill., *Syringopora perelegans* Bill., *S. Hisingeri* Bill., *S. Maclurei* Bill., *S. nobilis* Bill, *Stromatopora concentrica* Lonsd., *Cyathophyllum Zenkeri* Bill., *Zaphrentis prolifica* Bill., *Clisiophyllum Oneidaënse* Bill.,

Heliophyllum Eriense Bill., *H. exiguum* Bill., *Cystiphyllum Americanum* E. & H., *Blothrophyllum decoricatum* Bill., *Diphyphyllum Archiaci*[1] Bill., *Phillipsastræa Verneuili* E. & H., *P. gigas* Owen, sp., *Acervularia Davidsoni*[2] E. & H., *Tentaculites scalaris* Schlot., *Chonetes glabra* Hall, *C. hemispherica* Hall, *Strophomena hemispherica* H., *S. perplana* Con., *S. inæquiradiata* H., *S. demissa* Con., *Orthis propinqua* H., *O. Eryna* H., *Ambocœlia umbonata* Con. sp., *Spirifera gregaria* Clapp, *S. varicosa* H., *S. acuminata* Con. sp., *Leiorhynchus multicosta*[2] Hall, *Nucleospira concinna*[2] Hall, *Charionella scitula* Hall, sp., *Atrypa reticularis* Dal., *A. impressa* H., *A. aspera?* Hall, *Meristella unisulcata* Con., sp., *M. nasuta* Con., sp., *Leptocœlia concava* H., *Pentamerus aratus* Con., sp., *Stricklandia elongata* Vanux., sp, *Centronella glansfagea* Hall, sp., *Rhynchonella Thalia* Bill., *Lucina proavia* Goldf., *Conocardium trigonale* Hall, sp., *Platyceras Thetis* H., *P. crassum* H., *P. dumosum* Con., *Platyostoma strophius* H., *Murchisona Leda* H., *Proetus crassimarginatus* H., and more than two dozen species which seem to be undescribed.

If no reasonable doubt exists that these detached masses belong to the Corniferous limestone, the next question which presents itself relates to the region whence they have been derived. In view of the facts cited, it is evidently absurd to assume that no transportation has taken place; for these masses of Corniferous limestone are found resting over the Hamilton group, the Marshall group and the Carboniferous limestone—and, I am pretty well convinced, even in some cases, as far north as the Coal measures. There are insuperable objections to assuming that they have been transported with the great mass of drift materials from the northern outcrops of the rocks of this age at Mackinac and the surrounding region. *First*, the transporting agency has not moved masses of other kinds of rocks which attain to anything like the same dimensions. *Secondly*, That agency, if we may judge from the condition of the siliceous, trappean and gneissoid boulders of admitted northern origin, would have ground to powder so fragile and friable a rock as these limestones; or at least would have broken them into small fragments, and deposited them in a worn and rounded condition. *Thirdly*, If the Corniferous limestone could have been transported in such masses from its northern outcrops to southern Michigan, much more would the harder and more massive Niagara limestone of the same regions have been similarly

[1] These species of the Hamilton group are here included, because occurring in the same fragments with admitted Corniferous (and Schoharie grit) species. The Lower Helderberg *Leptocælia concava* is included for the same reason. In none of the cases just referred to, however, do we experience any difficulty in discovering slight constant peculiarities in the Corniferous species. The richness of the exotic Drift fauna of this locality, in the number and state of preservation of its remains, far exceeds any that has been signalized by the geologists of the Old World.

transported. The same may be said of the Trenton limestone. We find, however, that fragments of these limestones are of rare occurrence; and the fossils of Silurian age scarcely sustain to those of the Corniferous limestone the ratio of one to one hundred, in the drift deposits of the southern portion of the state. Even the Carboniferous limestone, whose outcrop extends through Kent, Eaton, Jackson and Oakland counties, is scarcely represented among the drift materials of the region in question. It is apparent that we must look in another direction for the origin of these lost rocks.

The nearest outcrop of the Corniferous limestone is in northern Indiana and Ohio, and the southeastern corner of Michigan[1]. Every fossil cited above is found in place in some part of that region. The formation dips under the peninsula of Michigan; and, throughout the area occupied by the lost masses in question, it lies from one hundred to twelve hundred feet beneath the surface—the depth of course increasing toward the center of the Carboniferous area. The circumstances suggest the exertion of some powerful agency acting northward with tremendous energy, but with a gentle and equable movement. It would seem as if the summit of the low anticlinal in the Corniferous limestone to the southeast of Michigan had been immersed in a shallow sea or lake, the freezing of which had incorporated the upper layers of the rock in an immense thickness of ice, which, by a rise in the water, had floated off as enormous ice-floes, bearing their cargoes of limestone northward till deeper and milder water loosened their icy hold, or they became stranded on the bosses which mark the belt of the Marshall sandstone. From the position of these masses in the "Modified Drift," as well as from the direction and gentleness of the movement, it would seem impossible that the events should have been contemporaneous with the actions which characterized the great glacial epoch.

Additional facts exist which seem to lead the mind further toward a belief in a northward acting post-glacial agency. The fossils of the Hamilton group, whose outcrop is along a belt lying somewhat farther north than the Corniferous limestone, are scattered through the soil of the region lying still farther north, in a degree of abundance which bears about the same ratio to that of the Corniferous fossils as the attenuated Hamilton rocks bear to the Corniferous. Indeed it may be said that *Spirifera mucronata* is the most abundant single species in our drift; as it was certainly the most abundant species that lived in these parts of the Lower Devonian sea. Other common species of the Hamilton group are *Ambocœlia umbonata* Hall, *Cyrtia Hamilton-*

[1] It probably underlies the drift materials of the southwestern angle of the state and the adjacent parts of Indiana, but no actual outcrops are known to exist.

ensis Hall, *Spirifera Marcyi* Hall, *Spirigera concentrica* Brown, sp., *Platyceras attenuatum* Hall, *Dalmania Boothi* Green, sp., and many others. These species exist in an admirable state of preservation, quite incompatible with the theory of their transportation from the far north; and they occur across a belt of the state reaching at least thirty miles north of the outcrop of the Hamilton rocks.

Again, above the identifiable Hamilton rocks, we find, in this state, a great thickness of argillaceous and bituminous shales, destitute of fossils, but freighted with Kidney iron ore. Nodules of this ore are strewn not only over the region of the outcrop of these "Huron" shales, but throughout Washtenaw and other counties lying over the upper Devonian and lower Carboniferous strata—to say nothing of the occurrence of such nodules within the limits of the Coal measures, where, by some geologists, they might preferably be referred to the indigenous strata.

Still again, the well marked fossiliferous beds of the Marshall sandstone, lying next above the Huron shales, and outcropping along a belt still farther north, is represented by a series of enormous fragments resting over the non-fossiliferous upper portions and the Carboniferous limestone. The lower, or fossiliferous portions of this formation do not outcrop farther north than Moscow, in Hillsdale county, while fragments of it have been transported in great abundance into the southern townships of Jackson county. The most notable example occurs in a deep railroad cut three miles north of Napoleon, where the abundant fossiliferous fragments led me for some time to suppose the actual outcrop must be in the immediate vicinity; although I had found the non-fossiliferous Napoleon sandstone intervening between the locality and the most northern known outcrop of the fossiliferous beds at Moscow. I collected here a large proportion of the common fossils of the Marshall group such as *Rhynchonella Sageriana*, *Chonetes pulchella*, *Myalina Michiganensis*, *Cardiomorpha modiolaris*, *Tellinomya Hubbardi*, *T. Stella*, *Pterinea crenistriata*, *Cardium Napoleonense*, *Solen scalpriformis*, *Bellerophon galericulatus*, *Orthoceras Indianense*, *Goniatites Marshallensis*, and numerous other species. The fossiliferous layers of the Marshall sandstone are decidedly friable—insomuch that it is in little request for building purposes—and it would seem absurd to suppose that these large fragments had been moved two hundred miles from the northern outcrop of the formation, when a transfer of ten or fifteen miles from the southern outcrop would bring them to the position which they occupy. We should expect, also, if derived from the north, that some contrast in the organic facies, due to local, if not to climatic causes, would present itself; but on the contrary, we find the fauna of

the fragments strictly identical with that of the nearest indigenous rocks of the same age.

The facts above cited recall some observations made several years since in Alabama, and which led at that time to impressions similar to those just set forth. My observations were made especially upon the neighborhood of the junction of the "Rotten Limestone" of the Upper Cretaceous, with the argillaceous and arenaceous strata of the Lower Cretaceous. The "Red Loam" of the central belt of the state, which I have evidences to prove to be but the Rotten Limestone altered *in situ*, or with slight transportation, has in many cases along the junction of the upper and lower strata, been moved northward over the clayey and sandy region appertaining to the lower Cretaceous; where, by its admixture with diluvial sand and pebbles, it is proved to be an exotic formation.

I forbear to express any belief in reference to the former existence of a transporting agency acting from the south to the north, over all or any portion of the interior of the continent; but such facts as I have cited cannot fail to call to mind the suggestions made some years since by President W. Hopkins, touching the course the Gulf Stream would necessarily pursue, in case of the subsidence of the North American Continent[4]. The facts are of sufficient importance to merit investigation; and it is to be hoped that other observers will inform us whether they are exceptional phenomena, or correspond, in connection with others, to some ancient, glacial or hydrographical area.

University of Michigan, August 4, 1865.

ART. XXXV.—*On the Crystallization of Sulphur and upon the Reaction between Sulphid of Hydrogen, Ammonia and Alcohol;* by CHARLES M. WETHERILL, Ph.D. M.D.

SULPHUR, in three of its four allotropic conditions, has been well studied, notwithstanding the difficulties which the rapid passage of (γ S) through (β S) to (α S) presents to experiments upon the first two modifications.

The most reliable specific gravities which have been assigned to the different forms of sulphur are the following:

	Marchand & Scheerer.	Deville.
Rhombic octohedral (α S)	2·045	2·07
Oblique prismatic (β S)	1·982	1·96
The red, amorphous (γ S)	1·957	1·91

[4] Quar. Jour. Geol. Soc., viii, 56. Reprinted, Am. Jour. Sci. and Arts, [2], xv, 72.

Regnault found the specific heat of (α S) = 0·20259, and Marchand and Scheerer that of (β S) = 0·20684. During the passage of (γ S) to (α S), a considerable amount of heat is evolved.

Hence in the red amorphous variety, the molecules are more widely separated, and are in a condition of unstable equilibrium. In satisfying their tendency to approach each other, they assume (by the fusion method) the *beta* form of prisms of the monoclinic system; but they soon pass into the condition of rest as rhombic octohedra (α S), of the trimetric system. This transformation takes place, as is well known in the solid prism, which is, without change of form, converted into numerous smaller crystals of (α S).

According to Frankenheim, "*gamma*" sulphur, like other so-called amorphous bodies, possesses the property of crystallization; but the manifestation of the phenomenon is prevented by the admixture of alpha and beta sulphur. Heat is the agent by which the (α) form is converted into the (β) and (γ) modifications, and has always been supposed to play an important part in the crystallization of this element. The ordinary or alpha sulphur, when crystallized from its solvents, sulphid of carbon, or oil of turpentine, reappears as octohedral alpha sulphur.

Frankenheim, however, observed that when the body is precipitated from its solutions at a temperature approaching its point of fusion, it assumes the prismatic form of beta sulphur.

Mitscherlich has shown that crystals of (β S) are transformed *immediately* into (α S), when dipped into a solution of sulphur in sulphid of carbon.

According to Pasteur, both forms of the element may crystallize from the above solvent.

M. E. Royer determined the crystallization from a turpentine solution, either in α or β crystals, according to the temperature. Thus, when fifteen grams of sulphur were heated with two hundred and fifty grams of oil of turpentine, the solution boiled at 158° C. Upon pouring one-half of the liquid into a glass vessel, so that a rapid cooling was effected, prisms were deposited; while the remainder cooled slowly, yielded octohedrons, and not a single prism.

Such experiments would appear to present an analogous condition to the prismatic crystallization by fusion, and subsequent change to the alpha form by rest. By the elevated temperature the molecules of sulphur are separated, and assume the relative positions required for (β S); while, during the slow refrigeration, they have time to arrange themselves into the rhombic octohedral form, in which they are in stable equilibrium.

Each of the allotropic conditions has probably a corresponding vapor density and its own chemical affinities.

The only known vapor density is that of (γ S); the others not having been determined from their transformation to this modification by the heat required for the experiment.

Upon the assumption that sulphid of hydrogen has an atomic constitution analogous to that of water, the specific gravity of the vapor of the sulphur in the compound is (by calculation) 2·21126; but Dumas and Mitscherlich determined the density of the vapor of sulphur (γ S) itself to be three times this number, or 6·63378. It has hence been inferred that the hydrogen sulphid is not constituted like water; but is composed of one volume of hydrogen to one-sixth of a volume of sulphur.

If, however, we were acquainted with the true vapor density of (α S), it may be presumed that a calculation involving this element would establish an analogous constitution for sulphid of hydrogen and water, two bodies resembling each other so much in their chemical behavior.

Otto supposes that sulphur occurs in H S and in most of its combination as (α S), and that perhaps in the persulphids of potassium &c., and in the sulphur acids which contain two, three, and four atoms of that element, it exists in the condition of β or γ sulphur.

When sulphur is dissolved in the fat oils at a moderate temperature, a large portion of the element separates on cooling as a yellow powder (α S); but if the temperature be elevated, as in the preparation of *balsamum sulphuris*, the sulphur remains in solution, probably as (γ S), and a tenacious gelatinous mass is the result of the reaction (Otto).

This chemist infers that since the vapor density of (γ S) is *thrice* that of (α S), the specific gravity of the vapor of (β S) is probably *double* that of (α S). If this assumption be correct we have in sulphur an allotropism like the the polymerism of compound bodies.

From these considerations, the question of the crystal form of sulphur in the act of separation from any of its compounds becomes one of great interest.

One of these instances, the subject of this article, has been presented accidentally to my notice.

An experiment was instituted to ascertain whether the presence of copper in alkaline solution (ammonia oxyd of copper) would determine a decomposition of glucose different from that effected by the alkali alone. The ammonia copper was added to a boiling solution of glucose until the blue color of the former was no longer discharged. Upon cooling, alcohol was added and then sulphid of hydrogen was passed through the liquid to separate the copper. On the next morning the filtrate contained a quantity of beautiful prismatic crystals of sulphur, of which some exceeded an inch in length. When spread upon filter paper to dry they became opaque, and broke up readily into granules.

To ascertain whether the products of decomposition of the

glucose effected the crystallization, a liter of 94 p. c. alcohol was, on July 4, 1864, saturated first with ammonia, then with sulphid of hydrogen, and was placed in a loosely stoppered bottle upon a shelf in the laboratory of the Smithsonian Institution, where it remained undisturbed until May 26, 1865.

At this time the sides of the bottle were coated with white, slightly nacreous crystals, which were more numerous upon the part of the bottle most exposed to the light. The formation of these crystals commenced upon the day after the saturation with the hydrogen sulphid. The solution was of brownish deep red color. The crystals measured $\frac{1}{8}$th of an inch in diameter, and, under the microscope, had the appearance of scales or plates, with rounded, ill-defined contour. A few appeared to be hexagonal and a very few were of spear shape. They were all completely soluble in water, more slowly so in alcohol, yielding a solution of faint acid reaction. They lost ammonia upon being heated with caustic potassa. Their solution treated with sulphuric acid evolved sulphurous acid and deposited sulphur. Heated upon platina foil they evaporated without previous fusion. Their taste was sharp and biting. Heated in a tube they yielded a deliquescent sublimate which contained sulphur. Their solution did not blacken acetate of lead, but gave a white precipitate with this reagent. With nitrate of baryta a white precipitate, insoluble in hydrochloric acid, fell after a short time. With nitrate of silver a precipitate was obtained which passed gradually from white through yellow and brown to black. It follows from these reactions that the crystals are hyposulphite of ammonia. Rammelsberg gives for the constitution of this salt the formula $3(NH_4O, S_2O_2,)+HO$.

If the experiments had rested at this point, the erroneous inference would have been drawn from them that the presence of organic matter (from the glucose,) occasioned the prismatic crystallization of sulphur; but the solution in the last example was filtered to remove the crystals; and the clear liquid was returned to the bottle. The crystals were washed upon the filter with a little alcohol, which was suffered to drop into the bottle and formed a stratum of a few lines in depth upon the surface of the dark colored solution.

On the next day a beautiful crystallization of sulphur in *prisms* was observed, and its advance was watched for several days. The crystals formed upon the sides of the vessel at the surface of the liquid, extended inwards, and developed themselves downward. In proportion as they grew, the liquid exchanged its dark red for a light amber color until the whole of the solution had acquired that tinge, the advance being from the surface, downward. The prisms were very slender, and terminated in planes oblique to the axis of the crystal. Not a single

octahedron was detected. By their insolubility in water, and by heating upon platina foil they were proved beyond a doubt to be sulphur. Some of the crystals measured over two inches in length; they were at first transparent, and of a canary yellow color.

On the second day after their appearance they had lost their transparency, and the microscope showed them to be full of fissures. Very minute crystals were formed upon the prisms and upon the sides of the bottle. Those occupying the latter position were magnified with a high power, and appeared to be bushes or star-shaped groups of *prismatic* crystals, radiating from a central *globular* and minute molecule. On the third day the latter crystals had become sufficiently developed to show that they were not prisms but rhombic octahedra, and that the crystals strung along the *primary prisms* like beads, were also rhombic octahedra. These crystals were all *truncated* as to their apices by planes perpendicular to the principal axes. The similar faces (O) of the lines of octahedra situated along the primary prisms were contained in parallel planes. These octahedra did not appear to have resulted from a breaking up of the primary prisms; but to be *deposited* upon the latter. I inferred that the prisms were at first (β S), in which a change to multitudes of octahedral crystals of (α S), contained within the prism, was effected; and that the contact of this group of (α S) crystals with the sulphur separating gradually from its solution determined the crystallization, *in the neighborhood of the altered prisms*, according to the alpha modification. It was remarkable that while this octahedral crystallization was going on, *transparent prismatic* crystals were forming in other parts of the solution, and I supposed at first that the *prisms* might belong to the trimetric system; but long observation of them assured me that they were monoclinic.

On June 4th the separation of the sulphur was complete from the liquid, which was of amber color. At this time other crystals in the form of transparent scales were forming. These were ascertained, by the taste and action of reagents, to be hyposulphite of ammonia. There was nothing new in the crystallization of the sulphur except the very instructive fact that where a prism had fallen from the side of the vessel to the bottom, the sulphur had crystallized in beautiful, well defined rhombic octahedra, with perfect apices, and which were as clear and colorless as rock crystal. They were arranged in rows, thus indicating the former positions of the prisms upon the bottle.

All of these crystals were first treated with water to dissolve the hyposulphite of ammonia. When this was performed under the microscope, the transparent scales were seen to disappear, and there remained octahedrons and prisms, some of which had imperfect octahedral crystals deposited upon them. The prisms appeared granular and were of canary color; the octahedrons

were almost white. When heated, and observed thus with the microscope, the crystals became of deep yellow color, and by elevating the temperature fused, yielding all of the characters of sulphur. It would seem to result from these experiments that sulphur exists in combination with hydrogen, (or perhaps with ammonium), in the B allotropic condition. We may readily conceive a change in the sulphur after it has been separated from the β to the α modification; but we cannot so readily imagine that it should leave its *alpha* form to assume the more unstable *beta* condition.

We have also here an example of the crystallization of (β S) *without heat.* Since the original prisms of *beta* sulphur are canary colored, and not of brownish tinge, it would seem that the prisms obtained by fusion owe their brown tint to γ sulphur. The hypothesis may be ventured that the color of (α S) is white or very pale yellow, that of (β S) yellow, that of (γ S) reddish brown and that of (δ S) nearly black.

In the reaction between sulphid of hydrogen in the alcoholic solution of ammonium, sulphid of ammonium, distinguished by its odor, is at first formed; the smell is gradually exchanged for a strong and persistent one of sulphid of ethyl until at least no ammonium sulphid can be, by the proper reagents, detected in the liquid. The sulphur is then contained in the clear solution partly as hyposulphite and in part as free sulphur dissolved, or in some manner kept from separating by the hyposulphite.[1] It is to this dissolved sulphur that the liquid owes its dark tinge, which depth of color came on gradually as the sulphid of ammonium was oxydized. When the solution lost a portion of its hyposulphite by crystallization, the free sulphur separated and the liquid lost its dark color. Then another portion of hyposulphite of ammonia appeared in crystals.

As the experiment has been set aside for further examination by slow crystallization, I am unable at present to say whether any sulphite of ammonia has been formed. The odor of free ammonia is very powerful, and the liquid contains sulphite of ethyl. A drop evaporated in the air upon a glass slide exhibits microscopic oil globules, having a strong smell of the sulphid of ethyl. The same globules may be absorbed by agitating the liquid with ether, precipitating by water, and suffering the ethereal solution to evaporate spontaneously in a watch glass.

The liquid also contains hyposulphite of ammonia in solution, and there are no crystals in it at present.

The following formula may illustrate its reaction:

$$3NH_4S+5O=NH_4O,S_2O_2+2NH_4O+S;$$

and for the sulphid of ethyl, perhaps,

$$NH_4S+C_4H_5O,HO=NH_4O,HO+C_4H_5S.$$

[1] Are γ S or β S soluble in the hyposulphite?

I cannot say whether mercaptan was formed; the odor appeared to be different from that of this alcohol, and there was no action by the solution on oxyd of mercury. I have regarded the formation of the ethyl sulphid as without influence upon the peculiar crystallization of sulphur here described. It may however be otherwise, for MM. Dietzenbacher and Moutier (C. R., lx, 353) have recently discovered that naphthaline, camphor, creosote, oil of turpentine, carbon, &c., modify the condition of sulphur rendering it soft and plastic, as well as partially insoluble in sulphid of carbon.

Art. XXXVI.—*On the History of Eozoön Canadense.*

WITH A PLATE.

In volume xxxvii of this Journal, at p. 272, will be found a note to one of the Editors from Sir W. E. Logan, dated Feb. 17, 1864, announcing the discovery in the Laurentian limestones of Canada of organic remains, which, after a careful microscopic examination had been pronounced by Dr. Dawson, to belong to a gigantic Rhizopod. On page 431 of the same volume is a further note by Dr. T. Sterry Hunt, dated April 2, 1864, in which he states that in these organic remains the calcareous skeleton remains unchanged, while the sarcode is replaced by certain silicates, pyroxene, serpentine, and a mineral allied to chlorite in composition; the minute tubuli of the fossil being injected by these silicates in a manner analogous to that presented by the tertiary and modern Rhizopods, which are filled with glauconite.

These were the first announcements of this remarkable discovery, which has since been zealously followed up. Specimens of this fossil, which Dr. Dawson has named *Eozoön Canadense*, have been submitted to Dr. W. B. Carpenter of London, who is well known to be the great authority on Rhizopods, and the result of his examinations has been to confirm completely the determinations of Dr. Dawson, and to add to the description by the latter some further structural details, which the more perfect specimens examined by Dr. Carpenter enabled him to detect.

The results of the various investigations of the Eozoön are found in four papers published in the Journal of the Geological Society of London, for February, 1865. The first of these by Sir W. E. Logan describes the general geological relations of the Laurentian rocks, and is accompanied by two sections which we reproduce below.

He also relates the history of the first discovery of the fossil, specimens of which were exhibited by him to the American Association, at Springfield in August, 1859—and were then re-

garded by him and by Prof. James Hall as organic, although the microscope had as yet failed to detect the beautiful structure since found in such perfection in the specimens from other localities.

Sir William Logan moreover recalls the fact that Dr. Hunt had already from the presence of iron-ore beds, graphite, and metallic sulphurets, argued for the existence of life during the formation of the Laurentian rocks. See on this point a paper read in Jan. 1859 before the Geol. Society of London, and published in the Journal of that society, of which a review will be found in this Journal, [2], xxx, 134. This view is further developed in Dr. Hunt's paper on American Geology in this Journal, [2], xxxi, 396, where he concludes on chemical grounds to "the existence of an abundant vegetation during the Laurentian period."

The second paper is by Dr. Dawson, and gives his zoological description of Eozoön and its affinities, with a lithographed plate. The third is an extended note by Dr. Carpenter, in which he fully confirms the sagacious determination of Dr. Dawson as to the rhizopod characters and foraminiferal affinities of Eozoön, and is illustrated with a wood-cut and ten lithographed plates. In the fourth place we have a paper on the mineralogy of Eozoön by Dr. T. Sterry Hunt.

These four papers are reprinted in the Canadian Naturalist for April, 1865, with a single lithographed plate containing selections from the three just mentioned, and with the addition of a nature-printed section of Eozoön, both of which we place before our readers, together with extracts of the papers.

The Eozoön has also been carefully studied by Prof. T. Rupert Jones, who in the Popular Science Review for April, 1865, has given an excellent paper on the geological and zoological relations of the new fossil, together with a colored plate. In addition to this the Intellectual Observer for May, 1865, contains an essay of twenty-four pages on the same subject by Dr. Carpenter, with two excellent plates. As a further contribution to the literature of Eozoön we may mention that the pages of the London Reader for June, contain a correspondence between Dr. Carpenter and Messrs. King & Rowney, of Galway, who venture to question the opinion of Messrs. Dawson, Carpenter and Rupert Jones as to the organic nature of Eozoön. This correspondence is chiefly interesting as giving from Dr. Carpenter the authorized announcement by Milne-Edwards, that he, after a careful study, fully concurs in the views of the latter named observers as to the structure and affinities of Eozoön.

We now proceed to notice Sir William Logan's description of the Laurentian rocks, the general facts in whose history are briefly given in a paper by Dr. T. Sterry Hunt in this Journal, [2], xxxvi, 222.

"The oldest known rocks of North America are those which compose the Laurentide Mountains in Canada and the Adirondacks in the state of New York. By the investigations of the Geological Survey of Canada, they have been shown to be a great series of strata, which, though profoundly altered, consist chiefly of quartzose, aluminous, and calcareous rocks, like the sedimentary deposits of less ancient times. This great mass of crystalline rocks is divided into two groups, and it appears that the Upper Laurentian or Labrador series rests unconformably upon the Lower Laurentian series. The united thickness of the two groups in Canada cannot be less than 30,000 feet, and probably much exceeds it. The Laurentian of the west of Scotland, also according to Sir Roderick Murchison, attains a great thickness." In that region the Labrador series had not until recently been certainly recognized, although from the descriptions of Mcculloch, and from an examination of the specimens collected by him, and now in the Museum of the Geological Society in London, Dr. Hunt in 1863, had expressed the opinion that the rocks of Skye belong to this series. (See as above, page 226.) Prof. Haughton of Dublin has since visited the islands of Iona and Skye, and confirmed the observations of Dr. Hunt. (Geol. Magazine, Feb. 1865, page 73.)

The labradorite and hypersthene rocks from that island are identical with those of the Labrador series in Canada and New York, and unlike those of any formation at any other known horizon. This resemblance did not escape the notice of Emmons, who, in his description of the Adirondack Mountains, referred these rocks to the hypersthene-rock of McCulloch, although these observers, on the opposite sides of the Atlantic, looked upon them as unstratified.

Sir William then proceeds to notice the ancient gneiss which in Bavaria and Bohemia underlies the primordial zone, with a great intervening mass of clay slates. This old gneiss, which is estimated by Gümbel and Crejci to have a thickness of 90,000 feet, may, as Sir William suggests, include both the Upper and Lower Laurentian, and perhaps the Huronian, which is believed to be more recent than the Labrador series, although the two groups have never yet been found in contact. He then proceeds to remark:

"The united thickness of these three great series may possibly far surpass that of all the succeeding rocks from the base of the Palæozoic series to the present time. We are thus carried back to a period so far remote, that the appearance of the so-called Primordial fauna may by some be considered a comparatively modern event. We however find that even during the Laurentian period, the same chemical and mechanical processes which have ever since been at work disintegrating and recon-

structing the earth's crust were in operation as now. In the conglomerates of the Huronian series there are enclosed boulders derived from the Laurentian, which seem to show that the parent rock was altered to its present crystalline condition before the deposit of the newer formation; while interstratified with the Laurentian limestones there are beds of conglomerate, the pebbles of which are themselves rolled fragments of an older laminated sand-rock, and the formation of these beds leads us still further into the past."

"In both the Upper and Lower Laurentian series there are several zones of limestone, each of sufficient volume to constitute an independent formation. Of these calcareous masses it has been ascertained that three, at least, belong to the Lower Laurentian. But as we do not as yet know with certainty either the base or the summit of this series, these three may be conformably followed by many more. Although the Lower and Upper Laurentian rocks spread over more than 200,000 square miles in Canada, only about 1500 square miles have yet been fully and connectedly examined in any one district; and it is still impossible to say whether the numerous exposures of Laurentian limestone met with in other parts of the province are equivalent to any of the three zones, or whether they overlie or underlie them all."

In this connection are given the two following sections, which serve to show the structure of the Lower Laurentian rocks, and their relation to the overlying Labrador and Lower Silurian series.

The Eozoön Canadense occurs at Grenville, and in the Petite Nation seigniory at the two points indicated in the first section, and in both places in the third or uppermost band of the Lower Laurentian limestone. The same fossil has also been obtained to the south of the Ottawa, in Burgess, and farther west at the Grand Calumet on the Ottawa, in both instances in a limestone band whose pre-

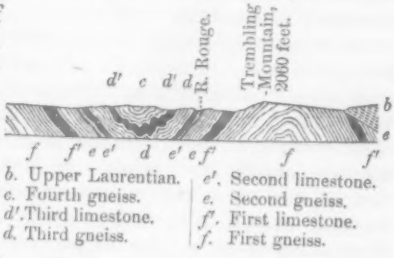
Fig. 1.—*Section from Petite Nation Seigniory to St. Jerome (66 miles).*

a. Lower Silurian.
b. Upper Laurentian.
b'. Upper Laurentian limestone.
c. Fourth gneiss.
d'. Third or Grenville limestone.
d. Third gneiss.
e'. Second or Green Lake limestone.
x. Porphyry; intrusive.
y. Granite; do.

cise place in the series has not been determined, nor is it known whether the fossil extends to the two lower conformable limestone bands, or to the calcareous zones in the unconformable Upper Laurentian series.

"The Grenville zone of limestone is in some places about 1500 feet thick, and it appears to be divided for considerable distances into two or three parts by very thick bands of gneiss. One of these bands occupies a position toward the lower part of the limestone, and may have a volume of between 100 and 200 feet. It is at the base of this limestone formation that the fossil occurs. This part of the zone is largely composed of great and small irregular masses of white crystalline pyroxene, some of them twenty yards in length by four or five wide. They appear to be confusedly placed one above another, with many ragged interstices, and smoothly-worn, rounded, large and small pits and sub-cylindrical cavities, some of them pretty deep. The pyroxene, though it appears compact, presents a multitude of small spaces filled with carbonate of lime, and many of these show minute structure similar to that of the fossil. These masses of pyroxene may characterize a thickness of about 200 feet, and the interspaces among them are filled with a mixture of serpentine and carbonate of lime. In general a sheet of pure dark green serpentine invests each mass of pyroxene; the thickness of the serpentine, varying from the sixteenth of an inch to several inches, rarely exceeding half a foot. This is followed in different spots by parallel waving, irregularly alternating plates of carbonate of lime and serpentine, which become gradually finer as they recede from the pyroxene, and occasionally occupy a total thickness of five or six inches. These portions constitute the unbroken fossil, which may sometimes spread over an area of about a square foot, or perhaps more. Other parts, immediately on the outside of the sheet of serpentine, are occupied with about the same thickness of what appear to be the ruins of the fossil, broken up into a more or less granular mixture of calc-spar and serpentine, the former still showing minute structure; and on the outside of the whole a similar mixture appears to have been swept by currents and eddies into rudely parallel and curving layers; the mixture becoming gradually more calcareous as it recedes from the pyroxene. Sometimes beds of

Fig. 2.—*Section across Trembling Mountain* (21 miles).

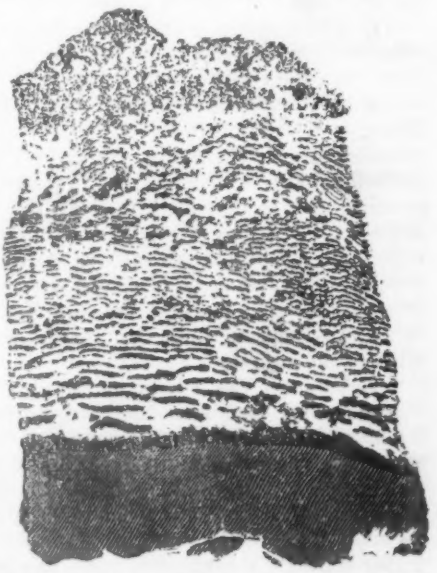


limestone of several feet in thickness, with the green serpentine more or less aggregated into layers, and studded with isolated lumps of pyroxene, are irregularly interstratified in the mass of rock; and less frequently there are met with lenticular patches of sandstone or granular quartzite, of a foot in thickness and several yards in diameter, holding in abundance small disseminated leaves of graphite."

"The general character of the mass produces the impression that it is a great Foraminiferal reef, in which the pyroxenic masses represent a more ancient portion, which having died, and having become much broken up, and worn into cavities and deep recesses, afforded a seat for a new growth of *Foraminifera*, represented by the calcareo-serpentinous part. This in its turn became broken up, leaving in some places uninjured portions of the general form. The main difference between this Foraminiferal reef and more recent coral-reefs seems to be that, while with the latter are usually associated marine shells and other organic remains, in the more ancient ones the only remains yet found are those of the animal which built the reef."

The structure and appearance of the unbroken fossil will be understood from the following nature-printed section, the preparation of which is thus described by Dr. Hunt.

"The replacing mineral in this specimen being serpentine, the calcareous septa were dissolved from the polished surface by the action of an acid, and the fine material replacing the tubuli having been removed by the aid of a brush, a wax mould of the etched surface furnished the electrotype cast from which the above figure is printed. The lights thus represent the calcareous skeleton, and the shaded portion a thick mass of serpentine, which is distinguishable from a contiguous thin stratum of the same mineral, that seems to form



3. Nature-printed section of a specimen of *Eozoön Canadense* from Petite Nation Seigniory.

the base of the Eozoön. The gradual passage from the wide chambers and thick septa to the narrower and thinner ones, and finally to the irregularly aggregated mode of growth, designated by Dr. Carpenter as *acervuline*, is well seen. The white patches in the upper portion of the figure do not arise from any imperfection in the electrotype, but represent the irregular growth of this part of the calcareous skeleton."

Slices of the fossils having been prepared for microscopic examination, and submitted to Dr. Dawson, were at once recognized by him as presenting the characters of Foraminiferal shells. After a careful examination of a large number of specimens he named and described the fossil as follows.

"EOZOÖN CANADENSE; *gen. et. spec. nov.*

General form.—Massive, in large sessile patches or irregular cylinders, growing at the surface by the addition of successive laminæ.

Internal structure.—Chambers large, flattened, irregular, with numerous rounded extensions, and separated by walls of variable thickness, which are penetrated by septal orifices irregularly disposed. Thicker parts of the walls with bundles of fine branching tubuli."

The grounds on which he inferred its foraminiferal character are thus stated by Dr. Dawson:

"1. The serpentine and pyroxene which fill the cavities of the calcareous matter have no appearance of concretionary structure. On the contrary, their aspect is that of matter introduced by infiltration, or as sediment, and filling spaces previously existing. In other words, the calcareous matter has not been moulded on the forms of the serpentine and augite, but these have filled spaces or chambers in a hard calcareous mass. This conclusion is further confirmed by the fact, to be refered to in the sequel, that the serpentine includes multitudes of minute foreign bodies, while the calcareous matter is uniform and homogeneous. It is also to be observed that small veins of carbonate of lime occasionally traverse the specimens, and in their entire absence of structures other than crystalline, present a striking contrast to the supposed fossils."

"2. Though the calcareous laminæ have in places a crystalline cleavage, their forms and structures have no relation to this. Their cells and canals are rounded, and have smooth walls, which are occasionally lined with films apparently of carbonaceous matter. Above all, the minute tubuli are different from anything likely to occur in merely crystalline calcspar. While in such rocks little importance might be attached to external forms simulating the appearances of corals, sponges, or other organisms, these delicate internal structures have a much higher claim to attention. Nor is there any improbability in the pres-

ervation of such minute parts in rocks so highly crystalline, since it is a circumstance of frequent occurrence in the microscopic examination of fossils that the finest structures are visible in specimens in which the general form and the arrangement of parts have been entirely obliterated. It is also to be observed that the structure of the calcareous laminæ is the same, whether the intervening spaces are filled with serpentine or with pyroxene."

"3. The structures above described are not merely definite and uniform, but they are of a kind proper to animal organisms, and more especially to one particular type of animal life, as likely as any other to occur under such circumstances; I refer to that of the Rhizopods of the order *Foraminifera*. The most important point of difference is in the great size and compact habit of growth of the specimens in question; but there seems no good reason to maintain that *Foraminifera* must necessarily be of small size, more especially since forms of considerable magnitude referred to this type are known in the Lower Silurian. Prof. Hall has described specimens of *Receptaculites* twelve inches in diameter; and the fossils from the Potsdam formation of Labrador, referred by Mr. Billings to the genus *Archæocyathus*, are examples of *Protozoa* with calcareous skeletons scarcely inferior in their massive style of growth to the forms now under consideration."

"These reasons are, I think, sufficient to justify me in regarding these remarkable structures as truly organic, and in searching for their nearest allies among the *Foraminifera*."

"Supposing then that the spaces between the calcareous laminæ, as well as the canals and tubuli traversing their substance, were once filled with the sarcode-body of a Rhizopod, comparisons with modern forms at once suggest themselves."

"From the polished specimens in the Museum of the Canadian Geological Survey, it appears certain that these bodies were sessile by a broad base, and grew by the addition of successive layers of chambers, separated by calcareous laminæ, but communicating with each other by canals or septal orifices sparsely and irregularly distributed. Small specimens have thus much the aspect of the modern genera *Carpenteria* and *Polytrema*. Like the first of these genera, there would also seem to have been a tendency to leave in the midst of the structure a large central canal, or deep funnel-shaped or cylindrical opening, for communication with the sea-water. Where the laminæ coalesce, and the structure becomes more vesicular, it assumes the 'acervuline' character seen in such modern forms as *Nubecularia*."

"Still the magnitude of these fossils is enormous when compared with the species of the genera above named; and from the specimens in the larger slabs from Grenville, in the Museum of

the Canadian Survey, it would seem that these organisms grew in groups, which ultimately coalesced, and formed large masses penetrated by deep irregular canals; and that they continued to grow at the surface, while the lower parts became dead, and were filled up with infiltrated matter or sediment. In short, we have to imagine an organism having the habit of growth of *Carpenteria*, but attaining to an enormous size, and by the aggregation of individuals assuming the aspect of a coral reef."

"The complicated systems of tubuli in the the Laurentian fossil indicate however a more complex structure than that of any of the forms mentioned above. I have carefully compared these with the similar structures in the 'supplementary skeleton' (or the shell-substance that carries the vascular system) of *Calcarina* and other forms, and can detect no difference except in the somewhat coarser texture of the tubuli in the Laurentian specimens. It accords well with the great dimensions of these, that they should thus thicken their walls with an extensive deposit of tubulated calcareous matter; and from the frequency of the bundles of tubuli, as well as from the thickness of the partitions, I have no doubt that all the successive walls, as they were formed, were thickened in this manner, just as in so many of the higher genera of more modern *Foraminifera*."

Dr. Dawson further ascertained that certain parts of the fossil present that irregular mode of growth which Dr. Carpenter has designated as acervuline, and moreover that considerable masses of Laurentian limestones are made up of fragments of the fossils. He further points out the presence in these limestones of other fragments, which are probably organic, and which may indicate the existence of other animal remains. Films of carbonaceous matter in some of these limestones also exhibit under the microscope forms which indicate that they may be the remains of plants. He further adds, that "although the abundance and wide distribution of *Eozoön*, and the important part it seems to have acted in the accumulation of limestone, indicate that it was one of the most prevalent forms of animal existence in the seas of the Laurentian period, the non-existence of other organic beings is not implied. On the contrary, independently of the indications afforded by the limestones themselves, it is evident that in order to the existence and growth of these large Rhizopods, the waters must have swarmed with more minute animal or vegetable organisms on which they could subsist. On the other hand, though this is a less certain inference, the dense calcareous skeleton of *Eozoön* may indicate that it also was liable to the attacks of animal enemies. It is also possible that the growth of *Eozoön*, or the deposition of the serpentine and pyroxene in which its remains have been preserved, or both, may have been connected with certain oceanic depths and conditions, and that

we have as yet revealed to us the life of only certain stations in the Laurentian seas."

Subsequent to the above examination and description by Dr. Dawson, specimens of the new fossil from Grenville, and also more perfect ones from a similar and newly discovered locality in the Petite Nation Seigniory were taken to London by Sir William Logan and submitted to Dr. Carpenter, who fully confirmed the above results, and made out some additional structure. More especially he observed in specimens from the new locality, the preservation of the fine tubulation of the original cell-wall, which had not before been clearly made out. The additional points are thus stated by Dr. Carpenter:

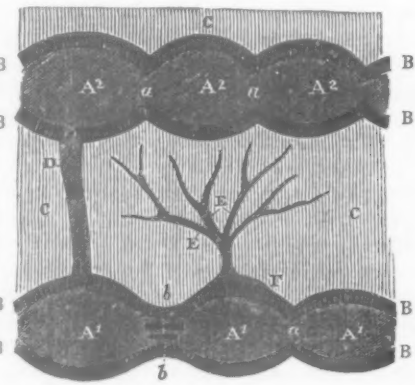
"Although Dr. Dawson has noticed that some parts of the sections which he examined present the fine tubulation characteristic of the shells of the Nummuline Foraminifera, he does not seem to have recognized the fact, which the sections placed in my hands have enabled me most satisfactorily to determine,—that the proper walls of the chambers everywhere present the fine tubulation of the Nummuline shell (plate, figs. 3, 6); a point of the highest importance in the determination of the affinities of *Eozoön*. This tubulation, although not seen with the clearness with which it is to be discerned in recent examples of the Nummuline type, is here far better displayed than it is in the majority of fossil Nummulites, in which the tubuli have been filled up by the infiltration of calcareous matter, rendering the shell-substance nearly homogeneous. In *Eozoön* these tubuli have been filled up by the infiltration of a mineral different from that of which the shell is composed, and therefore not coalescing with it; and the tubular structure is consequently much more satisfactorily distinguishable. In decalcified specimens, the free margins of the casts of the chambers are often seen to be bordered with a delicate white glistening fringe; and when this fringe is examined with a sufficient magnifying power, it is seen to be made up of a multitude of extremely delicate *aciculi*, standing side by side like the fibres of asbestos. These, it is obvious, are the internal casts of the fine tubuli which perforated the proper wall of the chambers, passing directly from its inner to its outer surface; and their presence in this situation affords the most satisfactory confirmation of the evidence of that tubulation afforded by thin sections of the shell-wall."

"The successive layers, each having its own proper wall, are often superposed one upon another without the intervention of any supplemental or intermediate skeleton such as presents itself in all the more massive forms of the Nummuline series; but a deposit of this form of shell-substance, readily distinguishable by its homogeneousness from the finely tubular shell immediately investing the segments of the sarcode-body, is the source of the

great thickening which the calcareous zones often present in vertical sections of *Eozoön*. The presence of this intermediate skeleton has been correctly indicated by Dr. Dawson; but he does not seem to have clearly differentiated it from the proper wall of the chambers. All the tubuli which he has described belong to that canal-system which, as I have shown, is limited in its distribution to the intermediate skeleton, and is expressly destined to supply a channel for its nutrition and augmentation. Of this canal-system, which presents most remarkable varieties in dimensions and distribution, we learn more from the casts presented by decalcified specimens, than from sections, which only exhibit such parts of it as their plane may happen to traverse."

"It does not appear to me that the 'canal-system' takes its origin directly from the cavity of the chambers. On the contrary, I believe that, as in *Calcarina* (which Dr. Dawson has correctly referred to as presenting the nearest parallel to it among recent *Foraminifera*), they originate in lacunar spaces on the outside of the proper walls of the chambers, into which the tubuli of those walls open externally; and that the extensions of the sarcode-body which occupied them were formed by the coalescence of the pseudopodia issuing from those tubuli."

We have here a diagram by Dr. Carpenter which he has given in his paper in the Quarterly Geological Journal; and from his subsequent memoir in the Intellectual Observer extract the following remarks: It will be understood that not only the chamber, but the canals and minute tubuli in the fossil are injected with serpentine, which, when the calcareous skeleton is removed by an acid, remains, and Dr. Carpenter especially notices "the marvellous completeness with which the minutest extensions of the sarcode-body of the animal are represented in decalcified specimens by these serpentine models; even



4. *Diagram illustrating the structure of Eozoön.*

A^1, A^1, A^1. Three chambers of one layer, communicating with each other directly at *a*, and by three passages through a shelly partition at *b*.

A^2, A^2, A^2. Three chambers of a more superficial layer.

B, B, B. Proper wall of the chambers, composed of finely tubular shell-substance.

C, C, C. Intermediate or supplemental skeleton, traversed by D, a stolon of communication between two chambers of different layers, and by E, E, a canal system originating in the lacunar space F.

the most delicate pseudopodial threads, consisting of the softest and most transitory form of living substance which were put forth through pores in the shell-wall less than one ten-thousandth of an inch in diameter, being thus perpetuated to all time." "The proper walls of the chambers are everywhere formed of a pellucid vitreous shell-substance minutely perforated with tubuli, so as exactly to correspond with those of *Nummulites*, *Operculina*, etc." The serpentine casts of these tubuli are frequently detached by the disengagement of the gas while the skeleton is being removed by an acid, but they often remain behind, standing side by side like the filaments which form the pile of velvet, their lower ends resting on the subjacent segment, while their upper extremities present a uniform surface. These casts of tubuli are distinguished from the adjacent serpentine, which is pale-green by their whiteness, yet the two are found by Dr. Hunt to be identical in composition, and thus, as he, and Dr. Carpenter after him, remarks, their whiteness is due to their fine division; many groups and bunches of this white substance being found by Dr. Carpenter to be aggregations of the elementary forms of sarcodic prolongation, which he has described in detail.

With regard to the intermediate or supplemental skeleton, which resembles closely that existing in *Calcarina* as described by Dr. Carpenter in his admirable Introduction to the Study of the Foraminifera, it is an exogenous deposit on the outer surface of the proper walls of the chamber, where it seems to be produced by the sarcodic layer which is formed by the coalescence of the pseudopodia after they have issued from the tubuli, and is traversed by a more or less minutely distributed canal-system, occupied during life by prolongations of that sarcodic layer. In those portions of the fossil where the chambers, instead of being regularly arranged in floors, are piled up in the *acervuline* manner, there is little or no trace of this intermediate skeleton, but in these irregularly aggregated chambers the structure of their proper walls is still well seen, both in transparent sections and in decalcified specimens.

In the solid masses of limestone which are made up of fragments of Eozoön, Dr. Carpenter could find no trace of the intermediate skeleton, though these specimens afford the most perfect examples of the Nummuline tubulation. He hence concludes that "the breaking up of the surface of the original Eozoön must have taken place before the proper walls of its highest tiers of chambers had been strengthened by exogenous deposit."

Space will not permit us to follow Dr. Carpenter in his comparison of Eozoön with other Foraminifera. He remarks, however, the resemblance in its mode of growth with the discoidal modern *Cycloclypeus* from the coast of Borneo, which attains a diameter of more than two inches and is made up of many

thousand segments, while in Globigerina the continuous increase of the individual body by segments soon ceases and new individuals are formed by the separation of the segments.

Reverting to Dr. Dawson's remark as to the important part played by the Eozoön in the Laurentian seas, Dr. Carpenter observes the significance of the fact that this lowest type of animal life known to the physiologist (the Rhizopod) should have attained such a great development and apparently culminated in the very earliest known period in the history of the life of our globe.

The serpentine marbles of Tyree and of Skye, whose probable Laurentian age had been pointed out by Dr. Hunt in the paper already cited, offer, according to Dr. Carpenter, "a structure clearly identical with that of the Canadian Eozoön." A like structure has been discovered by Mr. Sandford in the serpentine marble of Connemara, known as *Irish green* marble. "I have," says Dr. Carpenter, "examined decalcified specimens of several portions of this rock, and have not the smallest hesitation in identifying them with the acervuline portion of the *Eozoön Canadense*, although I have met with nothing corresponding to the lamellated structure of other portions of the Eozoön. Moreover in place of the continuous asbestiform layer covering the segments, long straight bundles of filaments radiate from them." The age of the Connemara rock is by no means certain. Sir Roderick Murchison was at first disposed to regard it as Laurentian, but has since expressed the opinion that it is of Silurian age.

In this connection we call the attention of American geologists and microscopists to the crystalline limestones of the Highlands of New York, which are doubtless of Laurentian age,[1] and also to the figure and description, given by Dr. Emmons on page 60 of his Geology of the 2nd district of New York, of a banded arrangement in rounded or oval masses of serpentine and carbonate of lime, much resembling in external form the Eozoön of Canada. The specimen figured by him is from Warrensburg, Warren County, New York.

The mode in which the Eozoön has been preserved by the injection of serpentine has already been noticed, but is further described in Dr. Hunt's paper, from which we make the following extracts:

"The details of structure have been preserved by the introduction of certain mineral silicates, which have not only filled up the chambers, cells, and canals left vacant by the disappearance of the animal matter, but have in very many cases been injected into the tubuli, filling even their smallest ramifications. These silicates have thus taken the place of the original sarcode,

[1] See this Journal, [2], xxxix, 97.

while the calcareous septa remain. It will then be understood that when the replacement of the Eozoön by silicates is spoken of, this is to be understood of the soft parts only; since the calcareous skeleton is preserved in most cases without any alteration. The vacant spaces left by the decay of the sarcode may be supposed to have been filled by a process of infiltration, in which the silicates were deposited from solution in water, like the silica which fills up the pores of wood in the process of silicification. The replacing silicates, so far as yet observed, are a white pyroxene, a pale-green serpentine, and a dark-green alumino-magnesian mineral, which is allied in composition to chlorite and to pyrosclerite, and which I have referred to loganite. The calcareous septa in the last case are found to be dolomitic, but in the other instances are nearly pure carbonate of lime. The relations of the carbonate and the silicates are well seen in thin sections under the microscope, especially by polarized light. The calcite, dolomite, and pyroxene exhibit their crystalline structure to the unaided eye; and the serpentine and loganite are also seen to be crystalline when examined with the microscope. When portions of the fossil are submitted to the action of an acid, the carbonate of lime is dissolved, and a coherent mass of serpentine is obtained, which is a perfect cast of the soft parts of the Eozoön. The form of the sarcode which filled the chambers and cells is beautifully shown, as well as the connecting canals and the groups of tubuli; these latter are seen in great perfection upon surfaces from which the carbonate of lime has been partially dissolved. Their preservation is generally most complete when the replacing mineral is serpentine, although very perfect specimens are sometimes found in pyroxene. The crystallization of the latter mineral appears, however, in most cases to have disturbed the calcareous septa."

"Serpentine and pyroxene are generally associated in these specimens, as if their deposition had marked different stages of a continuous process. At the Calumet, one specimen of the fossil exhibits the whole of the sarcode replaced by serpentine; while, in another one from the same locality, a layer of pale green translucent serpentine occurs in immediate contact with the white pyroxene. The calcareous septa in this specimen are very thin, and are transverse to the plane of contact of the two minerals; yet they are seen to traverse both the pyroxene and the serpentine without any interruption or change. Some sections exhibit these two minerals filling adjacent cells, or even portions of the same cell, a clear line of division being visible between them. In the specimens from Grenville, on the other hand, it would seem as if the development of the Eozoön (considerable masses of which were replaced by pyroxene) had been interrupted, and that a second growth of the amimal, which was

replaced by serpentine, had taken place upon the older masses, filling up their interstices."

The paper of Dr. Hunt contains numerous analyses of the various minerals noticed above. We extract his account of the loganite, which replaces the Eozoön from Burgess. The calcareous septa in these specimens are represented by a "somewhat ferriferous dolomite, the analysis of which was made upon portions mechanically separated from the enclosed silicate; it yielded carbonate of magnesia 40·7, carbonate of lime, with a little peroxyd of iron, 59·0=99·7. The septa of the specimen from this locality are in some parts more than 3·0 millimeters in thickness, and exhibit the chambers, cells and septal orifices; but no tubuli are seen. The replacing material has the hardness of serpentine, for which it was at first mistaken. Its color is blackish-green, but olive-green in thin sections, when it is seen by transmitted light to be crystalline in texture. Its fracture is granular, and its lustre feebly shining. It is decomposed by heated sulphuric acid, and was thus analyzed, yielding the result I. The centesimal composition of the soluble portion is given under II.

	I.	II.	III.
Silica	33·75	35·14	36·50
Alumina	9·74	10·15	10·80
Magnesia	30·24	31·47	28·20
Protoxyd of iron	8·19	8·60	9·54
Water	14·08	14·64	14·62
Insoluble sand	2·50	....	....
	98·51	100·00	99·66

"The silicate which here takes the place of the pyroxene and serpentine observed in the other specimens of Eozoön is one of frequent occurrence in the Laurentian limestones, and appears to constitute a distinct species, which I long since described under the name of loganite, and which occurs at the Calumet in dark brown prismatic crystals. I have since observed a similar mineral in two other localities besides the one here noticed. The result III, which is placed by the side of the analysis of the Burgess fossil, was obtained with a greenish-grey sparry prismatic variety from North Elmsley, having a hardness of 3·0, and a specific gravity of 2·539. These hydrous alumino-magnesian silicates, which I have included under the name of loganite,[1] are related to chlorite and to pyrosclerite in composition; but these last are distinguished from it by their eminently foliated micaceous structure."

"When examined under the microscope, the loganite which replaces the Eozoön of Burgess, shows traces of cleavage-lines,

[1] For a description of this and similar silicates, see Geology of Canada, p. 491.

which indicate a crystalline structure. The grains of insoluble matter found in the analysis, chiefly of quartz sand, are distinctly seen as foreign bodies imbedded in the mass, which is moreover marked by lines apparently due to cracks formed by a shrinking of the silicate, and subsequently filled by a further infiltration of the same material. This arrangement resembles on a minute scale that of septaria. Similar appearances are also observed in the serpentine which replaces the Eozoön of Grenville, and also in a massive serpentine from Burgess, resembling this, and enclosing fragments of the fossil. In both of these specimens also grains of mechanical impurities are detected by the microscope; they are, however, rarer than in the loganite of Burgess."

"From the above facts it may be concluded that the various silicates which now constitute pyroxene, serpentine, and loganite were directly deposited in waters in the midst of which the Eozoön was still growing, or had only recently perished; and that these silicates penetrated, enclosed, and preserved the calcareous structure precisely as carbonate of lime might have done. The association of the silicates with the Eozoön is only accidental; and large quantities of them, deposited at the same time, include no organic remains. Thus, for example, there are found associated with the Eozoön limestones of Grenville, massive layers and concretions of pure serpentine; and a serpentine from Burgess has already been mentioned as containing only small broken fragments of the fossil. In like manner large masses of white pyroxene, often surrounded by serpentine, both of which are destitute of traces of organic structure, are found in the limestone at the Calumet. In some cases, however, the crystallization of the pyroxene has given rise to considerable cleavage-planes, and has thus obliterated the organic structure from masses which, judging from portions visible here and there, appear to have been at one time penetrated by the calcareous plates of Eozoön. Small irregular veins of crystalline calcite, and of serpentine, are found to traverse such pyroxene masses in the Eozoön-limestone of Grenville."

Veins of fibrous serpentine (chrysotile) in like manner intersect the serpentine of this region, and are sometimes found cutting across the masses of Eozoön. It is stated in a note to this portion of the paper that, "Recent examinations have shown that some of these masses encrusted with Eozoön replaced by serpentine, consist of crystalline pyrallolite (rensselaerite); which seems, like the other silicates, to have replaced the organic matter of the Rhizopod."

"These observations bring the formation of siliceous minerals face to face with life, and show that their generation was not incompatible with the contemporaneous existence and the preserv-

ation of organic forms. They confirm, moreover, the view which I some years since put forward, that these silicated minerals have been formed, not by subsequent metamorphism in deeply buried sediments, but by reactions going on at the earth's surface.[2] In support of this view, I have elsewhere referred to the deposition of silicates of lime, magnesia, and iron from natural waters, to the great beds of sepiolite in the unaltered tertiary strata of Europe; to the contemporaneous formation of neolite (an alumina-magnesian silicate related to loganite and chlorite in composition); and to glauconite, which occurs not only in secondary, tertiary, and recent deposits, but also, as I have shown, in Lower Silurian strata.[3] This hydrous silicate of protoxyd of iron and potash, which sometimes includes a considerable proportion of alumina in its composition, has been observed by Ehrenberg, Mantell, and Bailey associated with organic forms in a manner which seems identical with that in which pyroxene, serpentine, and loganite occur with the Eozoön in the Laurentian limestones. According to the first of these observers, the grains of green-sand or glauconite from the tertiary limestone of Alabama are casts of the interior of Polythalamia; the glauconite having filled them by 'a species of natural injection, which is often so perfect that not only the large and coarse cells, but also the very finest canals of the cell-walls, and all their connecting tubes, are thus petrified and separately exhibited.' Bailey confirmed these observations, and extended them. He found in various cretaceous and tertiary limestones of the United States, casts, in glauconite, not only of *Foraminifera*, but of spines of *Echinus*, and of the cavities of corals. Besides, there were numerous red, green, and white casts of minute anastomosing tubuli, which, according to Bailey, resemble the casts of the holes made by burrowing sponges (*Cliona*) and worms. These forms are seen after the dissolving of the carbonate of lime by a dilute acid. He found moreover, similar casts of *Foraminifera*, of minute mollusks, and of branching tubuli, in mud obtained from soundings in the Gulf-stream, and concluded that the deposition of glauconite is still going on in the depths of the sea.[4] Pourtales has followed up these investigations on the recent formation of glauconite in the Gulf-stream waters. He has observed its deposition also in the cavities of *Millepores*, and in the canals in the shells of *Balanus*. According to him, the glauconite grains formed in *Foraminifera* lose after a time their calcareous envelopes, and finally become 'conglomerated into small black pebbles,' sections of which still

[2] This Journal, [2], xxix, 281; xxxii, 286. Geology of Canada, p. 577.
[3] This Journal, [2], xxxiii, 277. Geology of Canada, p. 487.
[4] This Journal, [2], xii, 280.

show under a microscope the characteristic spiral arrangement of the cells.[*]

"It appears probable from these observations that glauconite is formed by chemical reactions in the ooze at the bottom of the sea, where dissolved silica comes in contact with iron-oxyd rendered soluble by organic matter; the resulting silicate deposits itself in cavities of shells and other vacant spaces. A process analogous to this in its results, has filled the chambers and canals of the Laurentian *Foraminifera* with other silicates; from the comparative rarity of mechanical impurities in these silicates, however, it would appear that they were deposited in clear water. Alumina and oxyd of iron enter into the composition of loganite as well as of glauconite; but in the other replacing minerals, pyroxene and serpentine, we have only silicates of lime and magnesia, which were probably formed by the direct action of alkaline silicates, either dissolved in surface-waters, or in those of submarine springs, upon the calcareous and magnesian salts of the sea water."

In the second part of Dr. Hunt's paper on Natural Waters, published in this Journal for July, there will be found in § 41 some observations bearing on the formation of the silicates of lime and magnesia. The chemical and mineralogical relations of the Eozoön, or rather of its replacing silicates, are by no means the least important points in the history of this remarkable fossil.

Explanation of the Plate illustrating the Structure and Affinities of Eozoön Canadense.

Of the figures here given, 1, 3, 6 *a*, 6 *b*, and 7, are selected from two plates given by Dr. Carpenter to illustrate his paper; while 2, 4, and 5, are from the plates accompanying Dr. Dawson's description, and are from drawings by Mr. Horace H. Smith, the artist of the Canadian Geological Survey.

The figures, with the exception of 7, are from transparent sections of specimens in which the original shell was well preserved, and its minutest cavities infiltrated with serpentine. Figure 7 is from a specimen from which the calcareous skeleton was removed by an acid, and represents the internal casts of the tubes, as seen by reflected light.

Fig. 1. Vertical section of regularly stratified portion of *Eozoön* showing the ordinarily continuous connection of the chambers of each stratum; magnified 10 diameters.

2. Horizontal section of *Eozoön* from Grenville, magnified 25 diameters; *a*, systems of tubuli; *b*, secondary chamber.

3. Portions of two chambers of different layers, showing at *a*, *a*, the proper walls of their chambers; at *b*, *b*, the intermediate

[*] Report of United States Coast Survey, 1858, p. 248.

skeleton; and at *c*, *c*, a stoloniferous passage; magnified 25 diameters.

Fig. 4. One of the systems of tubuli cut transversely; magnified 100 diameters.

5. Part of a system of tubuli cut transversely; magnified 200 diameters.

6. Portions of the proper wall of the chambers, showing its Nummuline tubulation, as seen at *a* in longitudinal, and at *b* in transverse section; magnified 100 diameters.

7. Cast of the interior of canal-system; an entire group magnified 10 diameters.

Art. XXXVII.—*Notices of Earthquakes.*

I. *Notices of the Earthquake of August 17th, in the Mississippi Valley;* received from Dr. A. Wislizenus, of St. Louis.

1. *Note by Dr. Wislizenus.*—In the city of St. Louis the motion was felt by many persons in two distinct shocks, but lasting, in my estimate, not longer than about twenty seconds. Some observed its direction as going from north to south.

2. *Notice from the Missouri Republican, of St. Louis, Aug.* 18, 1865.—The shock of an earthquake was sensibly felt in this city yesterday morning at 25 minutes to 9 o'clock. The motion was an oscillating one, the earth seeming to swing gently, like the pendulum of a clock. It lasted nearly a minute and a half—the intermediate motions being slighter than was perceived at the beginning and end of the shock. During its duration, chamber furniture, gas fixtures, etc., could be seen to rock, and a cracking sound proceeded from the walls of the houses, as if their steadiness was seriously disturbed.

Cairo, Ill., Aug. 17.—A severe shock of an earthquake was felt here at $8^h\ 45^m$ this morning, causing people to rush out of their houses in the greatest consternation.

Jackson, Mississippi, Aug. 17.—The effect of the earthquake was seriously felt about 9 o'clock this morning at Memphis, Lagrange, Holly Springs, Oxford, and Grenada. At Memphis the shock was severe enough to cause people to run out of houses.

3. *Extracts from a letter to Dr. A. Wislizenus* by Mr. John T. Scott, Attorney at Law at New Madrid, Mo., dated Sept. 6, 1865.—On the morning of the 17th of August, about half-past 8 o'clock, I was going to my office, and having to proceed through a park, and being about the middle of it, and in the best possible position for hearing and observation, I heard, as I thought for the moment, heavy rolling thunder. This astonished

me, for it was almost entirely clear, no clouds whatever visible that in the least indicated thunder, rain, or change of weather. I was at this time going in a southeasterly direction, and the thunder, as for the moment I had taken it to be, seemed to be exactly in the opposite direction from that in which I was then going. Astounded as I was, I stopped, and, turning to ascertain from whence this noise proceeded, the earth began to vibrate to and fro from northwest to southeast, and continued for several times, the first vibration being the greatest (apparently not less than three or four inches), and gradually diminishing. On turning fully around, the noise which I had taken for thunder, but which, in fact, was the noise accompanying the earthquake, seemed to be about in a northwesterly direction from here; and had it been thunder, I should have thought it not over twelve or fifteen miles distant. It seemed to roll or pass off in a northeasterly direction, or at right angles to the vibrations of the earth. The noise and vibrations lasted about a minute.

In the town, the druggists' jars, bottles, &c., were all rocked to the very edge of the shelves, and some of them off. Chimneys were considerably damaged; dishes, cups, saucers, glasses, &c. suffered much. The cattle and dogs all ran in confusion and seemed much alarmed, and utterly at a loss to know where or in what direction to go.

I was talking to a ferryman here a few days since about the earthquake, and he told me that he was at the time crossing the Mississippi river in a skiff, and that the water rolled as if a steamboat had just passed. He said he was much frightened until he heard the noise and thought what it was. The fact is, however—and such was the case at the time referred to—that the noise generally precedes the shaking or vibration from one to three seconds. In this case I think it was about two seconds.

I would mention one fact, notorious here, that the earthquakes are much more severe in the swamp or low and inundated lands, than in the high and dry lands. Hence it is that those living west of here, in what is called Little River Swamps, and follow hunting for an occupation, often experience earthquakes when we feel none at all. The earthquake of the 17th, of which I am speaking, was much more severe there than here or in high and dry lands.

Another remarkable fact about the earthquakes here, is, that while sometimes the earth quakes or trembles, as it were, at other times it seems to roll in waves, like the ocean, and at others, as in the one I am more particularly speaking of at present, it vibrates, apparently, in a horizontal direction. They most generally come from the west or northwest, sometimes from the southwest. The character of the noise, or roaring, as it is generally called, is also variable.

May I not now suggest a plan by which valuable information, relative to the time, center, and progressive movement of these convulsions, might be obtained? Suppose there should be a correspondent at the county seat of every county in the vicinity of the region of earthquakes, whose duty it should be to note all the facts of each convulsion, its direction, its duration, &c., and forward the same to some scientific gentleman for comparison and analysis. Could not something be obtained by this means?

I am told that the most graphic description of the earthquakes of 1811 and 1812 is to be found in the works of Lorenzo Dow. This description is from the pen, and in a letter of Mrs. Elizabeth Bryan to that reverend gentleman, Mr. Dow. The old lady was residing here at the time, and is still here, in her 88th year. Perhaps you might glean something from that letter.

I would further remark that I did not conclude the above last evening, and just as I was writing the line above my signature, at a quarter past 8 o'clock this morning, the 7th, we had another shock, shaking houses, &c. considerably. It was not accompanied with much noise—came from a westerly direction, and lasted about half a minute.

II. *Notices*, received from Dr. C. F. Winslow, of Boston.

1. *Letter to Dr. Winslow*, from Mr. G. Pendleton, dated Rochester, Sept. 10, 1865.—In accordance with my promise I herewith send you the facts about the earthquakes I have experienced during my voyages in the Pacific ocean.

(1.) *Earthquake off Kamtschatka in* 1845.—The first case was as follows:—On board the ship Charles Phelps, at sea, September 22nd, 1845, Cape Kamtschatka bearing N.W., distance 15 to 20 miles; the weather clear, wind light and baffling from the westward. At about 8 A. M. we felt a heavy shock of an earthquake, causing the ship to tremble about as she would if going in stays in a strong wind; and the noise on board was much like the rolling of a heavy cask fore and aft the deck. It lasted about 15 to 20 seconds, and then passed off, and left all quiet.

(2.) *Earthquake at Guam, one of the Ladrones, in* 1849.—The next earthquake I find noticed as follows, in my journal:—Ship Mary & Susan, of Stonington, at Ulmata Bay, Island of Guam, January 24th, 1849. At 2·30 P. M. experienced the shock of an earthquake which was far beyond anything I have ever known before. It lasted for about one minute, and was followed by seven other shocks during the night, the last being at daylight of the 25th. The last seven shocks were much lighter than the first. At the time of the first shock, and during the night, the atmosphere was a little hazy, and had a very strong sulphurous smell. The earliest intimation we had of the first

great shock was an exceedingly great agitation of the water and the *land*. The convulsion on the land was so great that all of the brick and stone buildings on the Island were more or less injured, and some were reduced to a mass of ruins; and a man could not keep on his feet without holding on to something. I had a boat on shore at the time, and the inflood of the water was so great that it took her into the tops of the trees near the ocean, and swept water casks and such things a fourth of a mile or more into the country. And when the water receded, it left them with hundreds of *fish* high and dry, and the land at the watering place sank about twelve feet. When the water receded it took my ship back with such force that it parted my chain and I lost an anchor; she had run over it when the water flowed in and then went back with great force.

I would say that at the time of the first shock, and through the night, the wind was very light from the northeast. Several ships lying at Apra (the capitol of the Island) lost anchors by being covered up at the bottom of the harbor, and they had to part or cut their chains. I think there were six lost. The motion of the water on the Island was east and west.

2. *Notes from the Journal of Dr. C. F. Winslow.*—(1.) *Earthquake at Lima, March*, 1865.—T. J. Pope, Esq., Secretary of Legation to the Embassy of Peru at Lima, informs me that on the 1st of March 1865, at 6½ A. M., he was then on board the U. S. Ship Lancastre (acting as secretary to the Admiral), and his attention was called by the orderly to the strange agitation of the water in the bay. He states that the surface of the bay for a long distance around the ship was in a state of agitation and ferment, and that the water with wind was thrown up in jets from 12 to 15 inches. The odor of the sulphuretted or carburetted hydrogen was horrid, and the white paint of the ship was blackened. This occurred about the time (just before, in February,) when a great wave suddenly rushed into Callao bay and swept the bathing house away, and several persons drowned. There were several shocks of earthquakes about this time. But Mr. Pope felt no shock on the 1st of March, at the time of the phenomenon he speaks of.

Lima, April 20, 1865.

(2.) *Earthquake off Paita, May*, 1865.—At ¼ past 1 P. M., a strong earthquake was felt here which agitated the people very much. It lasted 20 seconds. This is experienced by me and is the strongest I have felt in Paita. Movement great from N.E.

Paita, May 15, 1865.

(3.) *Earthquake at Amotapa in Aug.* 1858.—In 1858, August 28, at 6·6 A. M., I felt a *very severe* earthquake at Amotapa. Made a crack in the river Chira, so that sulphurous fumes and

petroleum came to the surface. This was felt very far into the interior and was supposed to originate in the neighborhood of Longai. Mr. Woodhouse and Mr. Dewal both tell me of this earthquake, being then residents of this place or Paita. The earth trembled slightly very often for the next 24 hours.

Amotapa, May 27, 1865.

(4.) *List of Earthquakes, copied at Lima, from books given me by Mr. Wm. Sterling, of Amotapa, May* 28, 1865[1].—Earthquake in Lima, 1860, Apr. 21, 1·35 A. M.; pretty strong. At 12 o'clock, midnight, of 21st, a slight shock. 22nd, 1·40 P. M., a very heavy shock; walls thrown down and others cracked; some churches injured.—23d, 1 A. M., a light shock; at 6·40 A. M. same day, another very severe shock; at 11·30 A. M. same day, another severe shock accompanied with a loud rumbling noise; 5·45 P. M., another light shock.—23d, at 12, midnight, and on 24th at 12·30 A. M., and at 2 A. M., light shocks.—26th, 6 A. M., a loud rumbling with slight shaking. May 1st, 7 A. M., shock pretty hard. 20th, at 11·30 A. M., shock pretty hard.

(5.) *Letter of June* 8, *from Hon. C. Robinson, U. S. Minister to Peru.*—In 1865, on May 29, at 7·16 A. M., an earthquake was felt at Lima which was very violent and lasted 56 seconds. It was very alarming, but did no serious damage. The air was damp and heavy and misty. Temp. 64° Fah. Cool for Lima.

III. *Miscellaneous Notices.*

(1.) *Earthquake in California.*—At 12^h 45^m October 8th, an earthquake of great violence occurred at San Francisco. Chimneys were tumbled down, the walls of many buildings badly cracked, bells of steeples made to ring, and fissures two or three inches wide were opened in the lower part of the city. There were two violent shocks within half a minute. The accounts from Sacramento, Stockton and San José represent the earthquake as the severest ever felt in those cities. It was not perceived at Marysville or Placerville; but Santa Cruz was severely shaken and some buildings much damaged

The tide at San Francisco rose very high at the time of the shock and fell very low immediately afterward. Ten or eleven distinct shocks were felt after the first shaking, up to 5 A. M. of the 9th.

(2.) *Earthquake at Buffalo.*—The announcement of an earthquake at Buffalo in the last volume of this Journal (xxxix, 372), taken from a Buffalo paper, is an error.

[1] In Tacna, Sept, 19, 1860.

ART. XXXVIII.—*On Metabrushite, Zeugite, Ornithite and other minerals of the Key of Sombrero, W. I.*;[1] by ALEXIS A. JULIEN, Assistant in School of Mines, Columbia College.

SOMBRERO, a remnant of a coral Island, lying in lat. 18° 36′ N. and long. 63° 27′ W., varies in height from fifteen to forty feet, and comprises an area of about ninety-five acres. The quality and continued yield of the deposit of rock guano, which is disseminated in veins through the beds of limestone, have rendered its name familiar. During a residence of between three and four years (1860–1864), the following minerals have been observed by me, an unusual number for a formation of so recent geological origin and limited extent.

Calcite, and its phosphatic pseudomorphs.
Common salt, in cubes and in curved crystals.
Brushite, in massive specimens.
Metabrushite, and its pseudomorph, *zeugite*.
Ornithite, and its pseudomorphs.

1. *Calcite.*—This mineral, in its variety of massive, laminated, and stalactitic forms, is very abundantly dispersed throughout the fissures of the limestone, and small crystals though less common are not rare. All these display the ordinary characteristics of the mineral and possess no features worthy of notice.

However, a remarkable pseudomorphous process, consisting in the substitution of phosphoric for carbonic acid in the calcareous material of the Key, has taken place on a very extensive scale at various periods in its geological history. This has been effected by solutions of certain salts, from the superficial guano deposit, brought down by the rains into the joints of the limestone, and has given rise to various white, yellowish, and brownish materials. These are especially rich in the bone-phosphate of lime ($3CaO, PO_5$), containing about 85 per cent of that salt, also about 5 per cent each of phosphate of magnesia and carbonate of lime, with small percentages or traces of organic matter, sulphate of lime, oxyd of iron, alumina, and their phosphates, and fluorine. The masses of calcite in the vicinity of the guano-veins have participated in the same changes and thus interesting pseudomorphs have been produced, not only of the massive and stalactitic forms but of the crystals. Of the latter three varieties may be mentioned:

(1.) Those which consist simply of an ordinary crystal of calcite, overlaid with a brownish film of the phosphatic material.

[1] I take this opportunity to acknowledge my indebtedness to Prof. C. F. Chandler of the School of Mines, Columbia College, for the use of his private laboratory, (in which nearly the whole of this investigation has been made), and for his general assistance and advice; to Profs. O. N. Rood and C. A. Joy of the School of Mines, for the use of instruments and books; and to Prof. J. D. Dana of New Haven, for his crystallographic examinations.—A. A. J.

(2.) Hollow crusts, formed by the removal from the former of their cores of carbonate of lime.

(3.) Solid crystals, wholly consisting of the phosphatic material.

2. *Common Salt.*—The numerous pools of sea-water along the edge of the cliff, which are fed by the spray from the surf in high winds and heavy ground swells, sometimes evaporate considerably or wholly during the droughts of the winter season and the long calms of the summer. Thus, as in the large salt-ponds of neighboring islands, their bottoms are left sparkling with the ordinary cubical crystals of common salt.

But again, in September, 1863, a quarry in the northern part of the Key was partially filled by the overflow of a heavy ground-swell, and in this way masses of a porous variety of rock-guano were saturated with sea-water. The waters soon subsided through the bottom of the quarry and a peculiar efflorescence of salt afterwards appeared, near the sea level. It occurred over the surfaces of these masses on the sides of the quarry, in cavities shielded from the sun and rain, but otherwise freely exposed to the atmosphere. This crust consisted of slender crystals, usually one-eighth of an inch in length, white, translucent, and so much *curved* as to take, in some cases, one and a half turns, or to return to and become re-embedded in the matrix. In this last characteristic and in their fibrous structure they strongly resemble, especially under the microscope, the similar forms of gypsum, etc. Fracture uneven. A tendency is shown, (by the splitting of their terminations, the separation of narrow off-shoots from their sides, etc.), to a disintegration into the slender fibers of which each crystal seems to be an aggregation. There is also a transverse plane of cleavage, marked by the numerous lines of cross-fracture. In the thicker crystals the breadth is, in most cases, nearly uniform throughout their length; but in others it often decreases from one end to the other. The outer termination is usually rounded and sometimes a slender crystal ends in a sphere of greater diameter. The transverse section of every crystal is apparently almost circular, though irregular. The following are the results of an analysis:

	I.	II.
Moisture (expelled at 100° C),	·34	....
Loss by ignition,	·37	....
Guano, attached to the crystals,	1·53	....
Sulphuric acid,	·35	....
Chlorine,	58.72	58·73
Sodium,	37·39	....
Potassium,	·10	....
Magnesium,	·03	....
Lime,	·40	....
Aluminum,	·07	....
	99·30	

These results are equivalent to water ·55, guano 1·53, sulphate of lime ·75, chlorid of aluminum ·35, chlorid of calcium ·30, chlorid of magnesium ·11, chlorid of potassium ·20, and chlorid of sodium 95·46=99·25.

The crystals were found to be very deliquescent in an atmosphere saturated with moisture, absorbing more than their weight of water after a few days exposure. A sketch of a crystal magnified about fifteen diameters is given in fig. 1.

1.

3. *Brushite.*—A few small specimens of massive brushite, crystalline in structure and having a botryoidal surface, were found in one locality as crusts adhering to guano. Drusy cavities occur in this material, but no crystals like those from Aves Island, described by by Mr. G. E. Moore,[1] have yet been found. The following are the characters of this massive brushite: Hardness =2·76. Specific gravity =2·953–2·999, by two determinations of the coarsely powdered mineral in alcohol and in pure benzole, at 60° F. Luster vitreous, inclining to resinous; shining. Color white, but with a superficial yellowish tinge, (lighter than that of Moore's crystals). Streak and powder white. Translucent; in thin laminæ transparent. Fracture uneven. Brittle.

Gently heated in a closed tube before the blowpipe, it at once gives off water, darkens with a slight empyreumatic odor, and again whitens by ignition The water, condensed above, is decidedly acid, and gives the reactions for phosphoric acid. In the platinum forceps and on charcoal, it glows with a greenish light at a high temperature and fuses with a little intumesence to a button which is crystalline on cooling. At the same time it imparts a slight greenish tinge to the OFl, especially if previously moistened with sulphuric acid. With borax and with microcosmic salt it fuses easily, with a little effervescence, to a bead which is clear and colorless, both hot and cold; when nearly saturated, the bead is clear and slightly yellowish while hot, transparent and colorless when cold, and becomes milk-white and opaque by flaming; with a still larger excess it is slightly yellowish and transparent while hot, and becomes white and opaque on cooling. With carbonate of soda on charcoal it fuses readily to a clear and colorless glass. It dissolves easily (even after ignition) in nitric and hydrochloric acids, but very slowly in acetic and tartaric. When boiled with water in a test-tube the water gives a strong acid reaction with litmus; most

[1] This Jour., [2], xxxix, 43.

probably from the well-known decomposition of the salt, by hot water, into bone-phosphate and super-phosphate (CaO, 2HO, PO_5) of lime.

Two determinations were made of the amount of water in the air-dried material, the assay being successively heated in each case in an air-bath, at various temperatures from 100° to 245° C., and then ignited at a red-heat. The results were as follows:

	Temperature of expulsion.	I.	II.	Mean.
Hygroscopic moisture,	100° C.	1·388	1·071	12·29
Water, - - -	126°–240° C.	19·698	19·929	
Water and org. matter,	ignition.	6·111	6·155	
Combined water,		25·809	26·084	25·947
Total,		27·197	27·155	27·176

A tendency is thus exhibited to the expulsion of the four equivalents of water of crystallization (in the formula below) between 126°–240° C., the basic equivalent being retained until the temperature becomes much higher, or reaches ignition. The following is an analysis made with one gram of material:

		Oxygen Ratios.	
Moisture, - - - - - -	1·229		
Water and organic matter, -	25·947	23·06	2·52 5
Silica, - - - - - - -	*trace.*		
Sulphuric acid, - - - - -	·778		
Phosphoric acid, - - - - -	39·947	22·39	2·45 5
Magnesia, - - - - - -	*trace.*		
Lime, - - - - - - -	32·116	9·14	1· 2
Alumina and sesquioxyd of iron, -	·329		
Fluorine, - - - - - -	*trace.*		
	100·346		

These figures correspond to the following composition:

Moisture, - - - - - - - - - -	1·229	
Organic matter, - - - - - - - -	·346	
Sulphate of lime (CaO, SO_3+2HO,) - - -	1·675	
Alumina and sesquioxyd of iron, - - - -	·329	
Silica, phosphate of magnesia, and fluorid of calcium,	*traces.*	
Impurities,		3·579
2CaO, - - - - - - - - - -	31·569	
HO, - - - - - - - - - -	5·050	
PO_5 - - - - - - - - - -	40·004	
4aq. - - - - - - - - - -	20·200	
Brushite,		96·823
		100·402

The method, employed in this and all but one of the subsequent analyses, was as follows, the precipitates and filtrates

being treated in the usual way. The lime was first precipitated with sulphuric acid and alcohol. To the filtrate, evaporated to small bulk, citrate and aqua ammonia were added in excess, by which all the magnesia and a part of the phosphoric acid were thrown down as ammonio-phosphate. In the filtrate the remainder of the phosphoric acid was precipitated with the usual sulphate of magnesia solution. The filtrate was evaporated to a small bulk, digested in a flask with nitric acid until the complete expulsion of all chlorine, evaporated to dryness in a platinum dish, and calcined to perfect whiteness. The residue (excess of magnesia from the reagent) was redissolved in hydrochloric acid, the alumina and the oxyd of iron precipitated with aqua and carbonate of ammonia, and, after weighing, the iron redissolved and determined volumetrically, if desired. In the filtrate the alkalies if present were separated from the excess of magnesia.

In another portion of material, the water was determined as already explained, the ignited residue dissolved in nitric acid, and the chlorine and sulphuric acid successively estimated by additions of nitrate of silver and of nitrate of baryta.

4. *Metabrushite.*—This new mineral has been observed to occur only with the guano as a matrix, and in two localities in the northern part of the Key; in one, studding the sides of a cavity and attached in microscopic crystals to many small rootlets within it; and in the other, as a single large group, weighing about ten grammes, some of the crystals being nearly an inch in length and half an inch in breadth. The crystals are usually short, thick, and tabular, with most of their faces uneven and lusterless, unlike the prisms of brushite. The planes of cleavage are the same as in that mineral and in selenite, but are more imperfect. No massive specimens have yet been discovered. Its characters are as follows:

H. =2·75. Sp. gr. (with large crystals and distilled water at 60° F.) =2·288, 2·356, and 2·362. Luster vitreous, inclining to pearly, splendent on cleavage faces parallel to the clino-diagonal section; somewhat resinous on surfaces of irregular fracture. Color yellowish-white, sometimes with a slight reddish tint by transmitted light. Streak and powder white. Transparent; in some crystals, however, the surface is covered with a translucent film, by which their transparency is disguised and to which their reddish tinge is probably due. Fracture uneven. Brittle. It presents the same characteristics before the blowpipe and when treated with acids as massive brushite, except that it is apparently a little more slowly soluble in the mineral acids. It also exhibits strong double refraction.

In one assay the total loss of water by ignition was at once determined, and in three others, as in brushite, the loss at suc-

cessive temperatures from 110° to 400° C. was carefully ascertained.

	Temp. of expulsion.	I.	II.	III.	IV.
Moisture,	100° C.		1·620	1·515	1·380
Water,	126°–240° C.		17·983	17·419	17·191
Water and org. matter,	Ignition.	21·865	4·293	4·600	5·461
Combined water,			22·276	22·019	22·652
Total,		21·865	23·896	23·534	24·032

A tendency was noticed to the expulsion of one of the constitutional equivalents of water (in the formula below) at about 126° C., of the remaining two at 175°–180° C., a fraction of a per cent of water at 235°–239° C., and the basic equivalent on ignition; but the figures were somewhat variable. The quantity of material in my hands being small, the following analyses were made from an amount altogether a little less than two grams, according to the method already explained.

	I.	II.	III.	IV.	Mean.	Oxygen Ratios.		
Moisture,	21·865	1·620	1·515	1·380	1·505			
Water and organic matter,		22·276	22·019	22·652	21·826	19·40	2·07	4
Sulphuric acid,	none.	·208	none.	none.	·052			
Phosphoric acid,	42·527	42·688	43·103	42·565	42·721	23·95	2·55	5
Lime,	32·981*	32·731	33·346	32·849	32·977	9·38	1·	2
Magnesia,	·881	trace.	·645	·571	·524			
Alumina,	1·292	trace.	·505	·930	·795			
Sesquioxyd of iron,	·454							
	100·	99·523	101·133	100·947	100·380			

* By difference.

There was no trace of chlorine present, and no examination was made for fluorine. The results may be grouped as follows:

Moisture,	1·491	
Organic matter,	·717	
Sulphate of lime,	·068	
Phosphate of magnesia, ($3MgO, PO_5$),	1·147	
Alumina, oxyd iron, and phosphoric acid,	1·049	=4·472 impurities.
$2CaO$,	32·955	
HO,	5·277	
PO_5	41·844	
3aq.	15·832	=95·908 metabrushite.
	100·38	

While, therefore, brushite corresponds to the salt of Bödeker,[3] which contains four equivalents of water of crystallization and which was found by Ples[5] in almost pure acicular crystals in the central tissue of *Tectonia grandis*, we have in metabrushite the allied salt of Ræwsky[4] and Berzelius, the analysis (1) and theoretical composition (2) of which, by Berzelius, are as follows:

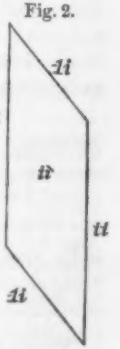
[3] Ann. Pharm, lxix, 206.
[4] Pharm. Centralbl., 848, 285.
[5] Rép. Chim. Appliq., xi, 324.

1.	2CaO, 34·39	HO, 5·50	PO_5, 43·61	3aq, 16·50	= 100.
2.	35·42	5·37	41·90	17·01	= 100.

Its relation to brushite and succession in amount of water have therefore been designated in the prefix of its name (*μετα*, *after*). In many of its characteristics it bears a strong resemblance to gypsum, a mineral which, it may be stated, does not occur upon the Key. I am indebted to Prof. J. D. Dana for the following results of his crystallographic examination of metabrushite and its pseudomorphs.

"System monoclinic. Occurring planes the prismatic *i*-*i* (orthodiagonal) and *i*-$\bar{i}$ (clinodiagonal) with a hemidome which may be lettered -1-*i*, as shown in the annexed sectional figure, (fig. 2,) *i*-*i* on -1-*i*=41° 30′−42° 30′, as measured with the common goniometer, but varying in some cases between 38° and 46°. . . . Large crystals, which vary from a fourth of an inch to an inch in length, often nearly half as broad as long, with commonly only *i*-*i* smooth, -1-*i* being crossed vertically by a few deep furrows and ridges, and rounding either side into *i*-$\bar{i}$, which is also uneven from a series of furrows parallel to those of -1-*i*, (see fig. 3). Cleavage clinodiagonal, easy and pearly. The crystals differ in the occurring planes from those of brushite, although like them in being of the monoclinic system, and in having a pearly clinodiagonal cleavage. They approximate moreover in the angle *i*-*i* : -1-*i*; for calculation gives for this angle in brushite (in which the plane -1-*i* does not occur) 41° 44′. The discovery of other crystals at Sombrero with additional planes, and those that are better for measurement, is necessary to settle positively the question of identity."

Fig. 2.



Pseudomorphs.—Pseudomorphous crystals (hollow crusts or shells) in considerable abundance have been found in certain localities in the course of quarrying. Of these at least the two following varieties may be unhesitatingly referred to metabrushite, possessing the same form and the peculiar furrowed planes.

3.

A. *Zeugite.*—H. =3·25. Sp. gr.=2·971. Color white, and with light shades of yellow and brown. Translucent. The crust in these crystals usually very thin, brittle, and fragile. The exterior surface is tolerably smooth (on the orthodiagonal plane,) though without lustre; but the interior, on being broken open, is extremely ragged and irregular. Both surfaces are often, but not always, completely covered with glittering points, which beneath the microscope are revealed to be tiny rhombs of calcite.

This rare variety of the pseudomorphs was found associated in the same cavity with the large group of crystals of metabrushite before mentioned in stellated, radiating, and irregular groups and drusy crusts, adhering to guano and also to the sides of cavities in the limestone. A few are also attached to the large group itself, showing the commencement of the pseudomorphous process. Two analyses of this material follow, of which I is the mean of two almost complete analyses of the same specimen, in which the phosphoric acid was determined by means of oxyd of mercury.

	I.	II.	Mean.
Moisture,	·08	2·97	3·02
Water and organic matter,	2·99		
Sulphuric acid,	·39	*trace.*	·19
Carbonic acid,	*trace.*	·48	·24
Phosphoric acid,	47·07	46·03	46·55
Magnesia,	3·25	3·92	3.59
Lime,	44·18	44·24	44·21
Alumina and sesquioxyd of iron,	·54	·78	·66
Fluorine,	*trace.*	*trace.*	*trace.*
Chlorid of sodium,	*undt.*	1·08	1·08
	98·50	99·50	99·54

In grouping together these results we must of course, in the first place give to the percentages of sulphuric and carbonic acids their equivalents of lime, and to that of magnesia sufficient phosphoric acid to form the salt, $3MgO, PO_5$. There only remain—

		Atomic ratios.	
Lime,	43·78	1·56	8
Phosphoric acid,	42·28	·59	3

If we calculate to the lime its proportion of phosphoric acid to form the bone phosphate, $3CaO, PO_5$, five per cent of phosphoric acid will still remain uncombined, except with the trifling quantity of alumina and oxyd of iron. From these considerations, necessary to elucidate the proper method of combining the results, (a question almost always a matter of great doubt and uncertainty,) the following arrangement seems the most probable:

Water and organic matter,	2·93
Sulphate of lime,	·41
Carbonate of lime,	·54
Phosphate of lime ($8CaO, 3PO_5$),	85·62
Fluorid of calcium,	*trace.*
Phosphate of magnesia,	7·86
Phosphates of alumina and iron,	1·10
Chlorid of sodium,	1·08
	99 54

This is therefore a new but accidental product, and although it is amorphous and there is no apparent relation between the constituents, (the phosphate of magnesia, alumina, etc., probably occurring in variable proportions, here as elsewhere,) nevertheless it differs somewhat in appearance from every other phosphatic material upon the Key, and is the only substance, I believe, in which this phosphate of lime, $8CaO, 3PO_5$, occurs in nature. This salt is the one whose occurrence in bones, as reported by Berzelius, as well as certain methods for its manufacture, were ascertained by Raewsky to be incorrect; but no evidence has been offered against its identity (with the addition, perhaps of some proportion of water) with the precipitate formed[a] by pouring chlorid of calcium, drop by drop, into a solution of phosphate of ammonia, containing an excess of ammonia, until half the phosphoric acid is thrown down. In the following table its composition, together with that of the bone phosphate of lime, are put side by side for the sake of comparison:

$8CaO$,	225·04	51·248	$3CaO$,	84·39	54·183
$3PO_5$	214·08	48·752	PO_5,	71·36	45·817
	439·12	100·		155·75	100·

In this case the salt has probably been formed by the union of an equivalent of the neutral phosphate of lime of the original crystals of metabrushite with two of the bone phosphate of lime of the pseudomorphous solution, and the old theory of its composition is thus confirmed, (rejecting the water:)

$$2CaO, PO_5 + 2(3CaO, PO_5) = 8CaO, 3PO_5.$$

To express, therefore, the junction in this mineral of metabrushite and ornithite, (soon to be described,) it may be called *Zeugite* (ζευγίτης, yoked or joined together,) and the other phosphates, etc., present, may be considered, as usual, impurities.

In the platinum forceps, before the blowpipe, it darkens with an empyreumatic odor, whitens, glows with a greenish light (though not so strongly as in the case of brushite and metabrushite,) but does not fuse, even upon thin edges. In a closed tube it darkens, with the odor, whitens, and gives off a very little hygroscopic water. With borax, microcosmic salt, and carbonate of soda, it acts like ornithite. When boiled in a test-tube with water, the latter becomes alkaline.

In cavities of the limestone in another locality of the Key, a variety of these pseudomorphs has been found in which the hemidome, $-1\text{-}\breve{i}$, is invariably covered with many small crystals. In the same cavities also occur large hollow hemispherical and botryoidal crusts. These are probably pseudomorphous crystals

[a] Berzelius, Traité de Chem., iv, 386.

of metabrushite, with the angles rounded off by a concretionary tendency in the pseudomorphous process, or they may be pseudomorphs of massive specimens of the mineral. Their material resembles that just described, in color, etc., (except that it is not drusy with calcite,) and it has probably the same composition.

B. Color straw yellow, buff, to dark shades of brown. Subtranslucent—opaque. Brittle. Crusts rather thicker than those of A, without the glittering surfaces. Found in isolated crystals, irregular groups, and drusy films, in cavities and fissures of the limestone, and in radiating groups upon stalactitic deposits of phosphate of lime. From their color and furrowed sides they often resemble little chips of wood.

C. Sp. gr. =2·988–3·030. Color straw yellow, buff, and shades of brown. Opaque. Brittle. Narrow blades, sometimes an inch and a quarter in length. In radiating or irregular groups. Crust thick; sometimes so much so that the crystals are nearly or quite solid. Occurs in limestone cavities. The following are a complete and a partial analysis of different specimens, the latter having been spoiled by an accident:

	I.	II.
Water and organic matter,	3·98	3·88
Sulphuric acid,	·18	—
Carbonic acid,	1·74	a little
Phosphoric acid,	43·24	—
Magnesia,	·56	—
Lime,	48·87	47·15
Alumina and sesquioxyd of iron,	1·02	—
Fluorine,	*trace.*	*trace.*
Chlorid of sodium,	?	—
	99·59	

In grouping these results by the method employed in the case of A, if we calculate the remainder of the lime as bone-phosphate, 3 per cent of phosphoric acid will remain uncombined except with alumina and iron. It seems more judicious, therefore, to suppose the existence of a mixture of the two phosphates of lime in this case, and arrange the analysis, for example, as follows: Water and organic matter, 3·90; sulphate of lime, ·39; carbonate of lime, 3·95; phosphate of lime ($8CaO, 3PO_5$), 35·28; bone phosphate of lime, ($3CaO, PO_{2,5}$) 52·49; phosphate of magnesia, 1·22; phosphates of alumina and iron, 2·36; fluorid of calcium, trace; =99·59. As the narrowness of the pseudomorphs of this variety is unusual among at least the known crystals of metabrushite, they may possibly be pseudomorphs of prisms of brushite, if such ever existed on the Key. In my first published statement[6] of the discovery of metabrushite, I errone-

[6] This Jour., [2], xxxvi, 424.

ously attributed to its composition the results of a qualitative examination of the foregoing pseudomorphous material. No analysis has been made of the material of variety B, but it is probable that in both B and C the material always consists of zeugite, with bone phosphate of lime (as well as the phosphates of magnesia, etc.,) as an impurity, in proportions increasing until perhaps the amount of $8CaO, 3PO_5$ becomes too small to be distinguished.

5. *Ornithite.*—In the empty casts of Madrepores and other cavities of the coral limestone, in two localities of the southern part of the Key, another new mineral occurs.

System monoclinic. Small crystals, not over a fourth of an inch in length, usually very narrow, with the planes even and not polished, and $-1\text{-}\bar{i}$ very slightly convex, resembling somewhat a common form of gypsum. Clinodiagonal cleavage perfect; so that this, unlike the other minerals, is easily sectile into very thin scales; two other planes, as in gypsum.

The broader crystals are arranged in radiating groups, while most of the narrower are isolated and strewn irregularly over the surfaces of the cavities. No massive specimens of the mineral have yet been found.

Hardness $=2{\cdot}5$; (just scratches mica when rubbed upon it). Lustre pearly on clino-diagonal surfaces. Color white. Streak and powder white. Translucent. Flexible.

When heated before the blowpipe in a closed tube, it darkens with a feeble empyreumatic odor, loses water, and again on ignition becomes white, opaque, and lusterless. It is probable that the water condensed above is neutral to the test-papers. In the platinum forceps and on charcoal, the mineral undergoes the same changes and does not fuse.[7] When previously moistened with sulphuric acid, the greenish tinge of phosphoric acid is imparted to the flame. With borax and with microcosmic salt it dissolves readily, and apparently with greater effervescence than in the case of massive brushite or metabrushite, to a bead which is clear and colorless both hot and cold; when nearly saturated, the bead is yellowish while hot, clear and colorless when cold, and becomes white and opaque by flaming: with a still greater excess, the bead is transparent and yellowish while hot, and becomes white and opaque on cooling. Readily soluble in nitric and chlorhydric acids. In thin scales it exhibits a feeble display of colors under the polarizing microscope.

The amount of this mineral in my possession being very small, only about one-tenth of a gram of pure crystals could be used for analysis, and it was first carefully dried at 100° C., with but

[7] On account of the small size of the fragments and their mobility before the blowpipe flame, I was unable to determine the effect of a long continued ignition; but at the end of a minute's ignition no trace of fusion could be perceived.

trifling loss. With this two water determinations were first made, from ·048 and .058 grame respectively of unbroken crystals, as follows:

	Temperature of expulsion.	I.	II.	Mean.
Water,	250° C.	3·918		....
Water and trace of org. matter,	strong ign.	5·154	9·827	....
Total,		9·072	9·827	9·449

A tendency is thus shown to the expulsion of one equivalent (in the formula obtained below) below 250° C., and the retention of the other until ignition. The ignited residues were combined and analyzed in the usual manner, with the following results:

		Oxygen ratios.	
Water and trace of organic matter,	9·449	8·4	1· 2
Phosphoric acid, - - -	40·139	22·5	2·67 5
Magnesia, - - - -	*trace.*		
Lime, - - - - -	45·768	13·2	1·54 3
Alumina and sesquioxyd of iron,	4·623		
	99·979		

No attempt was made to test for sulphuric acid and fluorine, traces of which may occur. These results correspond to the formula $3CaO, PO_5 + 2aq.$, so that this mineral is identical in composition with the gelatinous precipitate produced when the bone-phosphate of lime is thrown down from solution. The foregoing figures may be arranged as follows:

Organic matter, - - - - - -		*trace.*
Alumina, oxyd of iron, and their phosphates,		6·061
Phosphate of magnesia, - - -		*trace.*
3CaO - - -	45·768	
PO_5, - - -	38·701	
2aq., - - -	9·762	94·231
		100·292

I do not think that I can do better than to dedicate this species to my old comrades, the sea-birds of Sombrero, (ὄρνις, *a bird*,) to whom we are mainly indebted for the contribution of the guano-deposit to American agriculture, and for the formation of this interesting companion to apatite. Its physical characteristics, even more than those of metabrushite, correspond remarkably with those of gypsum, to which species it is also allied in its formula and mode of crystallization.

Pseudomorphs.—a. White and yellowish white crystals, with glittering surfaces and a material somewhat similar in appearance to the A of metabrushite; the crystals differ usually in their greater slenderness. These occur in cavities of the limestone, intermixed with the crystals of ornithite.

b. Hemispherical stellated groups. Color white. Opaque. Friable.

No analysis has been made of the material but I suppose it to be identical with that of the original crystals, *minus* the water. They occur intermixed with the original crystals; and also as solitary white groups, dotting over in marked contrast the dark brown phosphatic lining of cavities in the limestone.

In conclusion it may be observed that specimens of all these phosphatic minerals are exceedingly rare, few having been found since my departure from Sombrero (in the spring of 1864). Good specimens of the pseudomorphs are also uncommon, though imperfect or drusy crystals have occasionally been found in tolerable abundance on the opening of some new vein. It is a universal rule, when the original or the pseudomorphous crystals occur in cavities of the limestone, that they are never in direct contact with the matrix, a film or thin layer of a common brownish material, rich in bone-phosphate of lime, always intervening. As to my theory in regard to the origin and history of these minerals and of their pseudomorphs, I must refer to the coming publication of my general observations on Sombrero.

It is sufficient here to state that they have undoubtedly been deposited from the salts of the superficial guano-deposit brought down in solution by carbonated rain-waters into the joints of the limestone.

School of Mines, Columbia College, New York. June, 1865.

Art. XXXIX.—*On Two Varieties of Sponge-Spicules*;[1] by Alexis A. Julien.

In clearing the white coral-sand out of a crevice of the rock near the east cliff of the Key of Sombrero, W. I., a loose mass of snow-white acicular fibres was found, associated with fragments of coral, shells, etc., at the height of thirty-six feet above the sea, and imbedded in the sand at a depth of about three feet from the surface. Among these fibers the two following varieties were distinguished, the former composing the bulk of the mass:

A. Acicular, tubular, and gently-curving spicules (fig. 1, *a*), tapering from the middle toward each end, at first very gradually, and then rather suddenly at a short distance from the end, to a rounded point.

[1] My grateful acknowledgements are due to Prof. O. N. Rood of the School of Mines, Columbia College, for the use of his microscope and for general assistance and advice, and to Prof. C. F. Chandler of the School of Mines, for the facilities of his laboratory.—A. A. J.

The curvature of the ordinary spicules is in general very slight, and they are sometimes nearly straight. Among them, however, other forms occur (fig. 1, *b*) whose length is about the $\frac{1}{1000}$ of an inch, and whose curvature amount to that of a semicircle. These I take to be rudimentary spicules and suppose that they may lose their curvature in their enlargement.

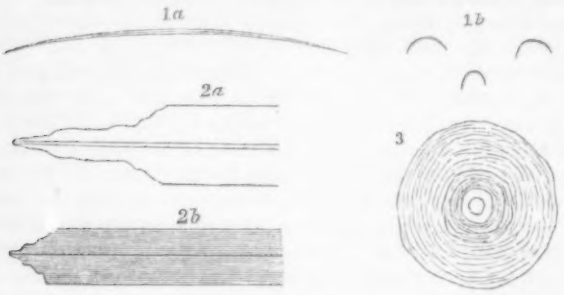


Fig. 1, magnified 14 diameters; fig. 2, 250 diameters; fig. 3, 727 diameters.

The sudden contraction near each end of a spicule occasions an irregular slope (fig. 2, *a*) or perhaps more frequently a series of from two to nine steps (fig. 2, *b*) consisting of a succession of curved planes. This slope is usually from $\frac{1}{1000}$ to $\frac{14}{1000}$ of an inch in length, and it not only varies greatly in length and form in different specimens, but sometimes at the ends of the same spicule.

The transverse sections of the spicules are generally circular, though sometimes somewhat elliptical, and the outer surface appears perfectly smooth. When the spicules are examined under a high power, a series of very fine parallel lines can be distinguished on either side of the central tube (fig. 2, *b*). In the transverse sections also (fig. 3), a series of very numerous but usually very faint concentric rings is often revealed, of which from three to five, adjacent to the center, are often most strongly marked and sometimes can alone be distinguished. We may therefore conclude that each spicule is constructed of a great number of enveloping sheaths. (They are much too remote in the figure.)

The section of the tube is generally circular, but sometimes triangular, elliptical, or oval. Its diameter diminishes, like that of the spicule, near each end, but the tube evidently extends through to the outer surface, since when an unbroken spicule is immersed in water the liquid enters the capillary tube by the orifice at each end. When magnified, a portion of a spicule bears a strong resemblance to a thermometer tube. The dimensions are:—

	Variation.	Mean.	No. of Measurem'ts.
Length, - - - - - - - - -	$\frac{1}{250} - \frac{1}{5}$ inch	$\frac{1}{4}$ inch	40
Diameter at middle, - - -	$\frac{1}{6000} - \frac{1}{100}$ inch	$\frac{1}{775}$ inch	58
" " end, - - - -	$\frac{1}{2000} - \frac{1}{333}$ inch	$\frac{1}{600}$ inch	15
Ratio of middle diam. to length,	$\frac{1}{25} - \frac{1}{1000}$	$\frac{1}{108}$	8
Ratio of middle to end diameter,	$\frac{1}{25} - \frac{1}{2}$	$\frac{1}{6}$	13
Diameter of central tube, - -	$\frac{1}{2000} - \frac{1}{1000}$ inch	$\frac{1}{3788}$ inch	45
Ratio of bore to diameter, -	$\frac{1}{10} - \frac{4}{7}$	$\frac{1}{3}$	45

The range in the variations of the measurements and of the ratios is consequently very considerable, and the same conclusion is impressed by a simple examination of a few spicules under a microscope, without measurement. Some of the longest spicules are the narrowest, and the thickness of the walls of the tube seems to bear no fixed relation to any other dimension.

A portion of the mass was carefully cleansed, by digestion with acidulated and with pure water, from the intermixed impurities, particles of sand, etc., and on analysis yielded the following results:

Water, - - - - -	7·902
Silica, - - - - -	89·84
Alumina, - - - - -	·29
Protoxyd of iron, - - - -	·09
Lime, - - - - -	·66
Magnesia, - - - - -	·22
Potassa, - - - - -	·63
	99·63

Hardness =3. Specific gravity =2·071. Color white. Luster pearly. Powder white. Transparent. Elastic. Easily ground to a very fine powder. Fracture conchoidal. Transverse planes of fracture very distinct; so that on coarsely pulverizing the spicula, very thin and beautiful transverse sections may be readily obtained among the fragments. The material does not possess double refraction.

In the platinum forceps or on charcoal, before the blowpipe, the spicules decrepitate slightly, whiten, lose their luster, and curl together into a coherent mass. When this mass is examined beneath a microscope, the ends of the spicules are found to be fused and in many cases blown into thin bulbs, or a series of bulbs occurs along their stems. This has evidently been effected by the fusion of their ends and the expansion of the air in the tubes. In a closed tube the spicules whiten, curl, and yield water. Unaffected by the acids, hot or cold, but readily soluble in a solution of caustic potassa.

B. Acicular, tubular, and gently-curving spicules, tapering gradually from the middle toward either extremity. Only about

a dozen specimens have been observed, all of which were fragments like that sketched in fig. 4. These fragmentary spicules differ from those of A in their minute size and in being marked by a series of from nine to sixteen nodes, each consisting of from four to eight sharp spines encircling the spicule. From their general correspondence to the spicules of A, in their curving and tapering outline and tubular character, as well as from an analogy (stated below) in regard to the number of the spines upon the nodes, I have ventured in fig. 4 to reproduce in lighter lines the lost portion of the spicule.

4.

Magnified 436 diameters.

The surfaces between the nodes are more or less concave, and the intervals, though nearly equal in the same spicule, vary from the $\frac{1}{6}\frac{1}{2}\frac{1}{5}\frac{1}{6}$ to the $\frac{1}{2}\frac{1}{3}\frac{1}{5}\frac{1}{0}\frac{1}{0}$ of an inch, averaging the $\frac{1}{3}\frac{1}{8}\frac{1}{4}\frac{1}{0}$: but this variation seems to be partly occasioned by the contraction of the intervals between a few of the central nodes, and in the larger specimens the length of the intervals (as well as the distance of the extreme node from the end of the spicule,) is quite regularly the $\frac{1}{2}\frac{1}{5}\frac{1}{0}\frac{1}{0}$ of an inch.

In the smaller spicules the nodes are crowded nearer together, are apparently composed of minute rounded projections, and resemble rings or raised fillets; but in the larger the spines are distinct.

These spines are acute and conical, like the extremities of the spicule. Their length varies slightly and irregularly among the nodes but never exceeds the $\frac{1}{1}\frac{1}{2}\frac{1}{8}\frac{1}{0}\frac{1}{0}$ of an inch.

The number of spines on each node diminishes from the fractured end towards the apex of the spicule, but in a progression which varies in different specimens. In the largest spicule found (fig. 4) the grouping of the spines seems to be as follows from one extremity of the perfect spicule to the other, supplying from analogy those upon the unseen side and upon the lost half of the spicule:

Groups.						
	3 nodes (terminal),	Spines on each node	4	total	12
	8 nodes,	" " "	6	"	48
	3 nodes (central),	" " "	8	"	24
	8 nodes,	" " "	6	"	48
	3 nodes (terminal),	" " "	4	"	12
Total,	25 nodes,				144 spines.

In the same way, another specimen had two central nodes of 8 spines each, five nodes on either side of 6 spines, and three terminal nodes of 4 spines: 100 spines in all. Again, in other

specimens, no 8-spined nodes seem to be present, but my o bser vations have been too few to determine the extent of the variation.

The central tube appears to pass uninterruptedly through th e nodes, to diminish in breadth towards the extremity of the spicule, and to present an open orifice there, into which the water enters when the spicule is immersed. The dimensions of thes e spicules are as follows:

	Variation.	Mean.	No. of Measurements.
Length, - - - - - - - - -	$\frac{1}{625} - \frac{1}{227}$ inch	$\frac{1}{357}$ inch	9
Diameter at middle, - - -	$\frac{1}{12500} - \frac{1}{3571}$ inch	$\frac{1}{5555}$ inch	9
" " end, - - - - -	? $- \frac{1}{8333}$ inch	?	1
" of central tube, - -	$\frac{1}{50000} - \frac{1}{25000}$ inch	$\frac{1}{30000}$ inch	3
Ratio of bore to diam. of spicula,	$\frac{1}{4} - \frac{1}{7}$	$\frac{1}{6}$	3

The chemical and physical characteristics of this variety are apparently identical with those of the former.

Both these varieties are related to the spicules of sponges, in their general characteristics; and I learn from Prof. A. E. Verrill that a sponge secreting such spicules exists in the West Indies. They may come from species of Hyalonema, which, according to published descriptions, are Gorgonioid corals having an axis of parallel siliceous fibers; but Mr. Verrill states that the species of Hyalonema are probably sponges. However this may be, there is a decided parallel arrangement in certain portions of the original mass, and even a firm cohesion of little bundles of the parallel fibers, which may imply that they were not disseminated through their organic matrix in the irregular manner usual to the spicules of a sponge, but occurred in a coherent mass of parallel fibers.

Although the mass of spicules is so light as almost to float, nevertheless it rapidly falls to pieces when placed in water. It is probable therefore that it has not been thrown up by the sea in its present form but is the residue from the decomposition of a sponge in the sand. Many sponges have been frequently thrown up by heavy ground swells at the locality in which the mass was found. The negroes state that similar white masses have been observed on the beach of the island of St. Martin.

School of Mines, Columbia College, New York. June, 1865.

ART. XXXIX.—*Researches on the Volatile Hydrocarbons;* by C. M. WARREN.*

OF THE CALCULATED BOILING-POINTS OF HYDROCARBONS BY SCHRÖDER'S THEORY.

THE subjoined tables exhibit the theoretical boiling-points of the above mentioned hydrocarbons,[1] as calculated according to Schröder's last theory, in comparison with the boiling-points actually found. By this theory, as already stated, each double atom of carbon (C_2) contained in a body is supposed to influence the boiling-point by 30°, and each double atom of hydrogen (H_2) to influence the same—10°; from the sum of these influences the number 70° is in all cases to be deducted, in order to find the boiling-point.

1. *Hydrocarbons from Pennsylvania Petroleum.*

1ST SERIES.

Formula.	Determined Boiling-point.	Calculated boiling point by Schröder's theory	Difference between Calculated and Determined boiling point.
	°	°	°
C_8H_{10}	0·0 (?)	0	
$C_{10}H_{12}$	30·2	20	10·2
$C_{12}H_{14}$	61·3	40	21.3
$C_{14}H_{16}$	90·4	60	30.4
$C_{16}H_{18}$	119·5	80	39.5
$C_{18}H_{20}$	150·8	100	50.8

2D SERIES.[2]

Formula (?)	Determined Boiling-point.	Calculated boiling-point by Schröder's theory.	Difference between Calculated and Determined boiling-point.
	°	°	°
C_8H_{10}	8–9	0	8–9
$C_{10}H_{12}$	37·0	20	17·0
$C_{12}H_{14}$	68·5	40	28·5
$C_{14}H_{16}$	98·1	60	38·1
$C_{16}H_{18}$	127·6	80	47·6

3D SERIES. (Not completed.)

Formula.	Determined Boiling-point.	Calculated Boiling-point by Schröder's theory.	Difference between Calculated and Determined boiling-point.
	°	°	°
$C_{20}H_{20}$	174·9	130	44·9
$C_{22}H_{22}$	195·8	150	45·8
$C_{24}H_{24}$	216·2	170	46·2

* Concluded from p. 232.

[1] To avoid useless repetition, the hydrocarbons from Albert coal oil will be omitted in this series of tables, they being considered identical with the corresponding bodies from petroleum.

[2] See foot-note on page 227.

2. *Hydrocarbons from Coal-tar Naphtha.*

Name of substance.	Formula.	Determined boiling point.	Calculated boiling-point by Schroder's theory.	Difference between Calculated and determined boiling-point.
		°	°	°
Benzole,	$C_{12}H_6$	80·0	80	0·0
Toluole,	$C_{14}H_8$	110·3	100	10·3
Xylole,	$C_{16}H_{10}$	139·8	120	19·8
Isocumole,	$C_{18}H_{12}$	169·9	140	29·8

3. *The Homologous Hydrocarbons from Oil of Cumin and Cuminic Acid.*

Name of substance.	Formula.	Determined boiling-point.	Calculated boiling-point by Schroder's theory.	Difference between calculated and determined boiling-point.
		°	°	°
Cumole,	$C_{18}H_{12}$	151·1	140	11·1
Cymole,	$C_{20}H_{14}$	179·6	160	19·6

It appears, therefore, that the theory of Schröder finds no support from any one of the different series of hydrocarbons presented in these tables. The discrepancy between the observed and calculated boiling-points, as shown, varies from about 10° to 50° C. This discrepancy is found to increase pretty uniformly by about 10° as we rise from one member to the next higher in the ascending series. In the series of the formula $C_n H_n$, however, the discrepancy is nearly a constant one, viz. about 46°. I would not overlook the fact, that the calculated boiling-point of benzole is absolutely identical with that found by experiment; nor the remarkable coincidence, that the agreement is almost perfect between the probable boiling-point, and that obtained by calculation, for the body of the probable formula $C_8 H_{10}$ in the 1st Series from petroleum. It is obvious, however, that these are merely accidental circumstances, to which no importance can attach.

Of the Calculated Boiling-points of Hydrocarbons by Löwig's Theory, viz. that One Atom of Carbon (C) raises the Boiling-point 38°·4, and One Atom of Hydrogen (H) lowers it 29°·2.

Hydrocarbons from Pennsylvania Petroleum.

1st Series.

Formula.	Determined boiling-point.	Calculated boiling-point by Lœwig's theory.	Difference between calculated and determined boiling-point.
	°	°	°
$C_8 H_{10}$	0·0 (?)	15·2	
$C_{10}H_{12}$	30·2	33·6	3·4
$C_{12}H_{14}$	61·3	52·0	9·3
$C_{14}H_{16}$	90·4	70·4	20·0
$C_{16}H_{18}$	119·5	88·8	30·7
$C_{18}H_{20}$	150·8	107·2	43·6

2D SERIES.[3]

Formula. (?)	Determined boiling-point.	Calculated boiling-point by Lœwig's theory.	Difference between calculated and determined boiling-point.
	°	°	°
C_8H_{10}	8–9	15·2	6·7
$C_{10}H_{12}$	37·0	33·6	3·4
$C_{12}H_{14}$	68·5	52·0	16·5
$C_{14}H_{16}$	98·1	70·4	27·7
$C_{16}H_{18}$	127·6	88·8	38·8

3D SERIES. (Not yet completed.)

Formula.	Determined boiling-point.	Calculated boiling-point by Lœwig's theory.	Difference between calculated and determined boiling-point.
	°	°	°
$C_{20}H_{20}$	174·9	184·0	10·9
$C_{22}H_{22}$	195·8	202·4	6·6
$C_{24}H_{24}$	216·2	220·8	4·6

A cursory examination of the last three tables will suffice to show that, so far as regards the hydrocarbons of the formulæ C_nH_n and C_nH_{n+2}, the theory of Löwig also has no foundation in fact. That his theory did not hold good with the hydrocarbons of the formula C_nH_{n-6} was observed by Löwig himself, who found that it would place the boiling-point of benzole at 285°·6, i. e. 205° above its actual boiling-point.

OF THE CALCULATED BOILING-POINTS OF HYDROCARBONS BY GERHARDT'S THEORY.

We come finally to test the law of Gerhardt, above mentioned. Inasmuch as this law was especially designed to apply exclusively to the hydrocarbons,—upon the observed boiling-points of some of which it was indeed founded,—we should naturally expect to find this more in accordance with facts than either the hypothesis of Schröder or that of Löwig, both of which claimed to be of more general application, and were framed more especially with reference to other classes of substances. The facts presented in the following tables will show, however, that this is

1. *Hydrocarbons from Pennsylvania Petroleum.*

1ST SERIES.

Formula.	Determined boiling-point.	Calculated boiling-point by Gerhardt's theory.	Difference between calculated and determined boiling-point.
	°	°	°
C_8H_{10}	0·0 (?)	−8·0	
$C_{10}H_{12}$	30·2	12·5	17·5
$C_{12}H_{14}$	61·3	33·0	28·3
$C_{14}H_{16}$	90·4	53·5	36·9
$C_{16}H_{18}$	119·5	74·0	45·5
$C_{18}H_{20}$	150·8	94·5	56·3

[3] See foot-note on page 227.

far from being the case; and that the theory of Gerhardt, as well as those of Schröder and Löwig, so far as these relate to the hydrocarbons, was by no means legitimately drawn from nature, but is altogether artificial.

2D SERIES.[4]

Formula. (?)	Determined boiling-point.	Calculated boiling-point by Gerhardt's theory.	Difference between calculated and determined boiling-point.
	°	°	°
C_8H_{10}	8–9	–8	16·5
$C_{10}H_{12}$	37·0	12·5	24·5
$C_{12}H_{14}$	68·5	33·0	35·5
$C_{14}H_{16}$	98·1	53·5	44·6
$C_{16}H_{18}$	127·6	74·0	53·6

3D SERIES.

Formula.	Determined boiling-point.	Calculated boiling-point by Gerhardt's theory.	Difference between calculated and determined boiling-point.
	°	°	°
$C_{20}H_{20}$	174.9	130·0	44·9
$C_{22}H_{22}$	195·8	150·5	45·3
$C_{24}H_{24}$	216·2	171·0	45·2

2. *Hydrocarbons from Coal-tar Naphtha.*

Name of substance	Formula.	Determined boiling-point.	Calculated boiling-point by Gerhardt's theory.	Difference between observed and calculated boiling-point.
		°	°	°
Benzole,	$C_{12}H_6$	80·0	93·0	13·0
Toluole,	$C_{24}H_8$	110·3	113·5	3·5
Xylole,	$C_{16}H_{10}$	139·8	134·0	6·0
Isocumole,	$C_{18}H_{12}$	169·9	155·5	15·5

3. *Hydrocarbons from Oil of Cumin and Cuminic Acid.*

Name of Substance.	Formula.	Determined boiling-point.	Calculated boiling point by Gerhardt's theory.	Difference between observed and calculated boiling-point
		°	°	°
Cumole,	$C_{18}H_{12}$	151·1	154·5	+3·4
Cymole,	$C_{20}H_{14}$	179·6	175·0	−4·6
Cumo-oil of turpentine,	$C_{20}H_{16}$	155·4	160·0	+4·6

The chief conclusions deduced from the foregoing facts and considerations may be briefly summed up as follows:

1. That the boiling-point difference for the addition of C_2H_2 in homologous series of hydrocarbons is generally 30° C., which is a much larger difference than has been commonly supposed.

2. That of the five series of hydrocarbons examined, only one series was found exceptional to the rule just stated, and this presented the boiling-point difference of about 20°, which is but

[4] See foot-note on page 227.

little larger than the number 19°, which Kopp found so common with other classes of substances.

3. That certain series of derivatives from the benzole series of hydrocarbons present boiling-point differences corresponding to the elementary difference of C_2H_2, considerably smaller than the number 19° of Kopp.

4. That the formulæ of Schröder, Löwig, and Gerhardt, for the calculation of boiling-points, so far as these may be supposed to relate to the hydrocarbons, are incorrect and purely artificial.

5. That the custom of taking boiling-points with the bulb of the thermometer in the vapor is more liable to lead to an erroneous determination, at least in certain cases, than if the bulb be placed in the liquid.

SCIENTIFIC INTELLIGENCE.

1. *Iron regions of Arizona;* by W. P. Blake (from a letter to J. D. Dana, dated San Francisco, Cal., Aug. 31, 1865).—Your note in the Journal (xxxix, 358,) upon the probable Azoic age of the iron ores of Mexico, described by Mr. Manross, induces me to send you a notice of the great abundance of specular iron ore in the upper part of Arizona, near Williams fork of the Colorado, observed by me in 1863. The ore is chiefly the micaceous variety, and occurs in thick beds and in thin sheets in a ferruginous limestone or dolomite, evidently metamorphic, and tilted at a high angle. The whole forms a belt of peculiar appearance, which may be traced by the eye for miles across the country in a direction a few degrees south of west, so as to pass over the Colorado, and into the limits of California. It is interstratified with chloritic and talcose slates, gneiss and granite, and the series has yielded both copper ores and gold. The iron ore is found in large boulders or blocks in most of the ravines; and as it resists decomposition by the weather better than the limestone, it stands out upon its surface in rough sharp ridges. Numerous specimens of similar ore were collected in the ranges north, and on the Cerbat and Aquarius mountains, by Lt. Whipple's party in 1863, of which Mr. Marcou was the geologist. It would thus appear that the ferruginous formation extends over a considerable area north and south, and it may possibly be connected with the Mexican series, and be pre-silurian. The antiquity of the Aztec and the Aquarius ranges and the metamorphic region about them, as compared with the Sierra Nevada and the Rocky mountains, was commented on by me in vol. iii, p. 59 of the Pacific R. R. Reports. At Williams fork a heavy white sand-rock and a conglomerate, of ancient appearance, overlie the granitic and metamorphic series unconformably. [If the above iron-bearing rocks are true pre-silurian, they afford, we believe, the first example yet published of such rocks being auriferous. The beds of iron ore to be of value as evidence of age should be of extraordinary thickness.—J. D. D.]

2. *On an oil-well boring at Chicago;* by Geo. A. Shufeldt, Jr. (From a letter to Prof. Eani, dated Chicago, Sept. 16, 1865, and communicated

for this Journal.)—I have recently bored a well at Chicago 711 feet in depth. The surface rock is the Upper Silurian; for the first forty feet it is porous and much decomposed; and it is so filled with petroleum that when exposed to the sun the oil oozes out, and the rock will burn almost like coal. From this rock, when the well was forty feet deep, I pumped 100 gallons of oil, but the fountains or sources of the oil were evidently much deeper, as the drill proved. The next stratum, 200 feet thick, is what we call here Joliet marble, from the name of the place where it outcrops; it is a yellowish-white stone and very compact, and affords no signs of oil. Next below, for 200 feet, there are bands of grey limestone with oil in the seams; then a band of shale, 156 feet thick, saturated with petroleum. This shale I understand separates the Upper and Lower Silurian, and where it (the shale) rests upon the underlying rock, oil was found in considerable quantities. Beneath this shale we entered the first band of sandstone rock of a reddish color, abounding in oil, and having a thickness of 71 feet.

At a depth of 711 feet we penetrated a stream of water which stopped further progress. This water is perfectly limpid, and is free from all traces of sulphur or other disagreeable minerals, and flows 500,000 gallons of water per day through a 3½ inch orifice. Its head is 120 feet above Lake Michigan.

3. *On the Drift in Brazil, and on decomposed rocks under the Drift;* from recent observations by Prof. Agassiz. Communicated for this Journal by Alexander Agassiz.—At Tijuca, a cluster of hills about 1,800 feet high, and about seven or eight miles from Rio, there is a drift hill with innumerable erratic boulders as characteristic as any ever seen in New England. Prof. A. had before seen unmistakable traces of drift in the Province of Rio and in Minas Geraes; but there was everywhere connected with the drift itself such an amount of decomposed rocks of various kinds, that it would have been difficult to satisfy any one not familiar with drift that there is here an equivalent of the northern drift. There is found at Tijuca the most palpable superposition of drift and of decomposed rocks, with a distinct line of demarcation between the two.

This locality afforded an opportunity of contrasting the decomposed rocks, which form a characteristic feature of the whole country, with the superincumbent drift, so as to be able hereafter to distinguish both, whether found in contact or separately. These decomposed rocks are quite a new feature in the structure of the surface of the country. Granite, gneiss, mica slate, clay slate, in fact all the various kinds of rocks usually found in old metamorphic formations are reduced to the condition of a soft paste, exhibiting all the mineralogical elements of the rocks as they may have been before they were decomposed, but now completely disintegrated, and resting side by side as if they had been accumulated artificially. Through this loose mass there were here and there larger or smaller veins of quartz rock, or of granite or other rocks, equally disintegrated; but they retain the arrangement of their materials showing them to be disintegrated veins in large disintegrated masses of rocks. The whole passes unmistakably to rocks of the same kind in which the decomposition or disintegration is only partial, or no trace of it is visible, and the whole mass exhibits then the appearance of a set of ordinary

metamorphic rocks. I tis plain that such masses forming everywhere the surface of the country must be a great obstacle to the study of erratic phenomena, and it is not wonderful that those who seem familiar with the country should entertain the idea that the surface rocks are everywhere decomposed, and that there is no erratic formation or drift here. But upon close examination it is easy to see that, while the decomposed rocks consist of the small particles of the primitive rocks, which they represent, with their veins and all other characteristic features, there is not a trace of larger or smaller boulders in them; while the superincumbent drift consisting of similar parts does not show the slightest sign of the indistinct stratification characteristic of the decomposed metamorphic rocks below it, nor any of the decomposed veins, but is full of various kinds of boulders of different dimensions. The boulders have not yet been traced to their origin; the majority consist of a kind of greenstone, composed of nearly equal amounts of a greenish black hornblende and feldspar. This greenstone is said by mining engineers to be found in the Entre Rios on the Parahyba, where iron mines are worked in a rock like these boulders. Thus far evidence has been furnished of the action of glaciers only in the extensive accumulations of drift similar in its characteristics to northern drift, but no trace has been found of glacial action, properly speaking, such as polished surfaces, scratches and furrows.

The decomposition of the surface rocks to the extent to which it takes place here is very remarkable, and points to a geological agency thus far not fully discussed in our geological theories. It is obvious that the warm rains falling upon the heated soil must have a very powerful action in accelerating the decomposition of rocks; it is like torrents of hot water falling for ages in succession upon hot stones, and instead of wondering at the amount of decomposed rocks, we should rather wonder that there are any rocks left in their primitive condition.

4. *Mining Statistics of Great Britain for* 1864.—

	Produce of mines.
Coal,	92,787,873 tons.
Iron ore,	10,064,890 "
Pig iron,	4,767,951 "
Copper ore,	214,604 "
Metallic copper,	13,302 "
Lead ore,	94,433 "
Metallic lead,	91,283 "
Silver (from lead ore),	641,088 ounces.
Zinc ores (nearly all sulphuret),	15,407 tons.
Metallic zinc,	4,040 "
Iron pyrites (for sulphuric acid and soda works),	94,458 "
Tin ore,	15,211 "
Metallic tin,	10,108 "
Gold (from Merionethshire),	2,887 ounces.

The gross value of the above mineral products was 39,979,837*l*. There were 2,351,342 tons of coal taken to London in 1864 and 1,786,713 tons in 1863. Eight and a half millions of tons of coal were exported in 1864, and nearly half a million of tons of iron.—*Athen., Aug.* 19.

5. *Cretaceous Reptiles of the United States*, by JOSEPH LEIDY, M.D. 136 pp. 4to, with 20 plates. From the Smithsonian Contributions to Knowledge, vol. xiv, 1865.—Dr. Leidy has here described in detail and figured with great beauty and perfection, the Saurian remains of the American Cretaceous. The species included are the following *Thoracosaurus*:

Bottosaurus Harlini, undetermined species of *Crocodiles*, *Hyposaurus Rogersii*, *Discosaurus vetustus*, *Cimoliosaurus magnus*, *Piratosaurus plicatus*, *Mosasaurus*, *Macrosaurus lævis*, *Polygonodon vetus*, *Hadrosaurus Foulkii*, undetermined reptiles allied to *Hadrosaurus*, *Astrodon Johnstoni*, *Tomodon horrificus*, *Pliogonodon priscus*, *Chelonia*, *Chelone sopita*, *Chelone ornata*, *Emys firmus*, *Emys beatus*, *Emys pravus*, *Platemys sulcatus*, *Bothremys Cookii*, *Trionyx priscus*.

6. *Note on the Discovery of Rhizopods in the Azoic;* by JAMES D. DANA.—It may be thought that the recent discovery of the Eozoön in the Laurentian of Canada is at variance with the writer's Manual of Geology, in which the Laurentian is styled *Azoic*. But in truth the book and facts are in more perfect harmony for the discovery made since its publication. The author suggests on page 147 that Rhizopods may have existed in the Azoic along with lime-secreting marine vegetation, as the sources of the material of the Azoic limestone strata; and on page 596, after alluding to marine locomotive (animal-like) Protophytes with other Algæ as probably commencing in the Azoic, and as the *first* of comprehensive types, it is added:

"The Protozoans (Rhizopods, etc.) may have been the *associated* species of the *superior* group, as remarked on page 147. The two are alike in extreme simplicity of organization. In Algæ the Radiate type of structure, characteristic of the typical plant, is not brought out; and in Protozoans neither of the four great Animal types appears,—the Radiate, Molluscan, Articulate, or Vertebrate. If, therefore, these simple species existed in the Azoic era, they were *systemless* life, and only foreshadowed the great systems of life which were afterwards displayed according to their respective types in the true *Zoic* ages."

The reader will apprehend the full bearing of this sentence if he will re-peruse the chapter on the Progress of Life from which it is taken.

7. *Report on the Mines of New Mexico;* by Prof. R. E. OWEN, Geologist, and E. T. Cox, Geologist and Chemist. 60 pp. 8vo. Washington, 1865.—This pamphlet gives a brief notice of the general geology of the region examined. It mentions a five-foot bed of bituminous coal of Cretaceous age in the Raton Mountain close to the stage road; and two miles N.E. of Santa Fe, a thin bed of coal with coal-plants and other fossils (*Productus Cora*, *P. semireticulatus*, &c.) of the Carboniferous formation. At the Organ Mts., in the southern part of the territory, the Carboniferous limestone is converted into crystalline marble; and at the Hannover copper mines, it is partly fossiliferous, and partly so crystallized as to resemble the adjoining granite rock. In the same region there is a bed of magnetic iron ore, "forming a belt 75 to 100 feet wide," and near the junction with the stratified rocks there is an iron breccia. The carboniferous limestone, with *P. Cora*, was found in the Jemez valley and Cañon of San Diego. Near the Placer Mtn., a bed of true anthra-

cite, nearly 5 feet thick, exists, due to a porphyritic dike intersecting the Carboniferous formation which is much tilted. The authors state that this metamorphism and disturbance must have taken place after the Carboniferous age.

8. *Defense des Colonies:* III, Etude Générale sur nos Etages G–H, avec application spéciale aux environs de Hlubocep, pres Prague; by JOACHIM BARRANDE. 368 pp. 8vo., with a chart and a sheet of profiles. 1865. Prague and Paris.—Barrande has discussed in this work the subject of "Colonies" as connected with the distribution of Paleozoic fossils, in a way to command attention and excite an interest in his views. The volume is also very valuable for the review it gives of the paleontology of Bohemia. No justice to the work can be done in a brief notice—which is all that our space in this number will allow; and we commend the volume entire to all interested in geological science.

9. *Supplement to the Ichnology of New England.*—A Report to the Government of Massachusetts in 1863. By EDWARD HITCHCOCK, D.D., LL.D., late Professor of Geology in Amherst College. 96 pp. 4to, with 20 plates. Boston, 1865.—This Report, the last work of the late Professor Hitchcock, contains descriptions and illustrations of new species of tracks, among which are some strange forms, well termed enigmatical. A number of the plates are fine photographs, a style of illustration especially important for the minute tracks, like those of insects, and excellent for all. The bones of the right foot of the Saurian remains found near the water-shops of the Armory at Springfield, and partly described and commented upon by Professor J. Wyman at p. 187 of the Ichnology, are figured on one of the plates of this Supplement. The opinion of Professor Owen of London is given that they belonged to a Saurian with an unusually thin and compact wall of bone in the limb bones, which, however, might have been occupied by unossified cartilage, as in the young crocodile and turtle; if they were filled with oil or light marrow, it would indicate a relation to Pterodactyles or Birds. The species is named *Megadactylus polyzelus.*

10. *New Dinosaurian from the Wealden Formation, Isle of Wight.*—A new Dinosaurian, for which Prof. Owen has proposed the name *Polyacanthus* (from *πολυς many* and *ακανθος spine*), has been found by Rev. W. Fox. The animal was over 6 feet long from the shoulder to the rump, had a massive tail 5 feet long, legs about 4 feet long, and a broad short foot. It had a bony armor made of plates from ½ in. to 4 in. broad, and ½ in. thick, excepting along the back, over which there was a great bony shield; and along the sides of the body and tail there were spine-like bones, some of which are 15 in. long and weigh 7 pounds.—*Athenæum, Aug.* 5.

11. *Seaside Studies in Natural History;* by ELIZABETH C. AGASSIZ and ALEXANDER AGASSIZ. Marine Animals of Massachusetts Bay. RADIATES. 156 pp. 8vo. Boston, 1865. (Ticknor & Fields.)—The tendency of summer travel to the seashore is creating a demand for popular works on the life of the waters. The "Seaside Studies" will be welcomed as a beautiful and attractive beginning in this department of literature. We say beginning, because it takes up but a single branch—that of the Radiates, and is confined mainly to the species of Massachu-

setts Bay. The work is exact in its science as well as popular in style, and is in fact a contribution to science which the most learned may read with profit. The text is mainly from the graceful pen of Mrs. Agassiz, and the work is dedicated to her husband, Prof. L. Agassiz. The illustrations are numerous and excellent, and the printing and paper all that could be desired.

12. *Entomological Society of Philadelphia.*—The publication committee of this Society propose to publish, and issue gratuitously, an occasional bulletin, under the title of "The Practical Entomologist," in which papers on the insects injurious and beneficial to vegetation will be given for the benefit of the American farming interest. They express in their circular (dated September, 1865,) the hope that the information imparted through this medium will be of use to the agriculturists of the country, by leading them to study critically the Entomological fauna which surrounds them, and to derive, from their knowledge thus acquired, the power to increase the production of their crops and develop the interest which they represent. It is a singular fact that some of our commonest and most injurious insects are least known. Our Cotton, Hop, and various other crops suffer at times immensely from insects whose habits we little understand. The Society aims by its publication to bring out the true history of each and all of our noxious insects; and it is believed that, this attained, simple remedies will suggest themselves, which in certain cases may be merely burning the stubble and vigorous fall ploughing.

They ask, in order that their plan may be carried out, that those having information will send it by letter to the Secretary of the institution, at No. 518 South Thirteenth Street, Philadelphia, along with alcoholic phials containing specimens of the noxious insects of the region. They also desire papers from scientific observers for the "Practical Entomologist," as only the active coöperation of all interested parties will insure success in an undertaking which is a labor of public benefit, without moneyed recompense.

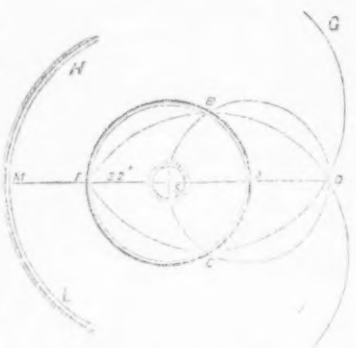
13. *A classification of Mollusca based on the Principle of Cephalization;* by EDWARD S. MORSE. 20 pp. 8vo. From the Proceedings of the Essex Institute.—A very valuable original paper, based on researches in Molluscan development and bearing on the general subject of zoological classification. We may cite from the paper in a future number.

14. *Natural History: A Manual of Zoology for Schools, Colleges, and the General Reader;* by SANBORN TENNEY, A. M., author of "Geology," Prof. Nat. Hist. in Vassar Female College. 540 pp. 12mo; illustrated with 500 wood cuts. New York. 1865. (C. Scribner.)—The American student in zoology will find Prof. Tenney's Manual a very convenient and useful work. It goes over the animal kingdom, commencing with the highest class, that of Mammals, and illustrates the various subdivisions with descriptions and figures, mentioning and figuring particularly North American species. Each of the prominent groups is thus presented to the eye by means of excellent wood-cuts of animals accesible to the American student, and with a large number of them considering the size of the work. The Manual is well calculated to make the study of zoology popular and easy. It fails of any introductory chapters on the structure of animals.

15. *On a solar halo, seen at Crawfordsville, Ind.*, (lat. 40° 03′); by Prof. J. L. CAMPBELL. (In a letter to the Editors, dated Wabash College, Crawfordsville, May 27, 1865.)—Herewith I submit a report of the remarkable appearances in the atmosphere on May 26th, 1865.

The morning was hazy and cool—the thermometer at 5 ranging about 48° to 50°.

About nine o'clock a series of halos or rings began to form about the sun, and continued to increase in brilliancy until near noon—then slowly disappeared during the afternoon—traces being visible at six o'clock in the afternoon. The accompanying diagram is a correct representation of the phenomenon as it appeared at twelve o'clock, noon.



S (Sun), Primary center; A, Secondary center; B and C, Tertiary centers; Radius, SE=22°=AD, SM=44°; MD, Grand axis =88°; Barometer 29·72 in.; Thermometer 70° F.

The most brilliant ring was described about the sun as a center with an angular radius (SE) of twenty-two degrees by careful measurement.

The bands were *white*, *yellow*, *red* and *green*. The white was exceedingly brilliant. The yellow and red were also very bright.

The breadth of this series of bands forming the primary ring was about one and a half degrees.

The arc MLG described about the sun as a center with a radius of forty-four degrees presented less brilliant, but well defined colors in the *reversed* order,—the white band being on the outer circumference, and the green within,—with another inner band of violet.

At A on the circumference of the primary circle, the center of the second circle was located. The radius of this circle was the same as that of the primary—its *circumference passing directly through the sun.*

The ring was chiefly white light, of less brilliancy than the primary, yet very sharply marked throughout its entire circumference.

From D the arcs DF and DG branched off symmetrically with reference to the axis MSD, indicating the centers of curvature at B and C, the intersections of the secondary circle with the primary.

These arcs were of white, well defined, mellow light.

The long continued and well defined manifestation of the phenomenon enabled us to take all our observations very carefully, and to repeat them for further accuracy.

The geometrical relations of the centers of these curves are curious and interesting, and the record of these positions may be of some value in connection with future observations of the same character.

In explanation of these appearances there are some difficulties not hitherto presented in discussing halos. For the present the record of the facts only is made.

16. *British Association at Birmingham.*—The meeting of the British Association opened at Birmingham on the 6th of September, Professor Phillips being the President. The number of members at the meeting during the week following was about 1,400, and besides these there were present 508 ladies and 23 foreigners. The funds received amounted to 2227*l.*; and nearly this amount was set apart for various scientific investigations in astronomy, physics, zoölogy, geology, &c., including 35*l.* for oyster culture. The number of papers read was two hundred and sixty. We have no space in this number for a notice of the Proceedings. The next meeting will be held at Nottingham.

17. *Systema Naturæ of Linnæus.*—By letter from Prof. A. E. Nordenskiöld of Stockholm we learn that the Academy of Sciences of Sweden is about to have printed a new photo-lithographic edition of the first edition of Linnæus's Systema Naturæ; and he adds, that "To enable us to judge how many copies may be sold it would be of some interest to have an idea of the probable extent of its sale in the United States." This first edition of Linnæus consists of only 13 to 14 leaves in folio and still contains the rudiments of all his great productions.[1]

18. *New Planet.*—Planet No. (54) was discovered on Aug. 25, by Dr. Luther, of the Observatoray at Bilk, near Düsseldorf. On the day of discovery at 10h. 46m. 28s., Bilk mean time, its A. R. was 323° 37′ 49·1″, and its declination N. 14° 20′ 47·1″. It has been named Clio.

19. *Italian Society of Natural Sciences.*—An extraordinary meeting of this Society was held at Spezzia on the 17th of September.

20. *Prof. Berthelot.*—A chair of Organic Chemistry has been founded at the College of France, and Prof. Berthelot appointed to fill the place.—*Reader, Sept.* 2.

21. *Statue of Arago.*—An inauguration of the statue of Arago, erected at his birthplace, Estagel, in the Basses Pyrenees, took place on the 31st of August. His son, dissatisfied that he had not received a special invitation, and because there was no commemoration of his father's political services, declined to be present.—*Reader, Sept.* 9.

21. *Chambers's Encyclopedia.*—Parts 94, 95, 96, 97 of this valuable Encyclopedia, extending to RID., have been issued by the American publishers, J. P. Lippincott & Co.

OBITUARY.

Admiral William Henry Smith.—Admiral Smith died at his residence near Aylesbury, Sept. 9th, at the age of 77. He had acted as President of the Astronomical Society, and of the Geographical Society, Vice President of the Royal Society, and Director of the Society of Antiquarians. He retired in 1825 from naval life, and published in 1844 the "Cycle of Celestial Objects," including the "Bedford Catalogue," an excellent hand book of practical Astronomy, a result of a series of astronomical observations in his Observatory at Bedford. He also published many works or memoirs on Geographical and other subjects.—*From a notice in Reader, Sept.* 16.

Hugh Cumming, died in London, on the 10th of August last, at the age of 74. He commenced his journeyings in behalf of natural his-

[1] If persons desiring the book will so write the Editors of this Journal they will communicate the result to the Swedish Academy.

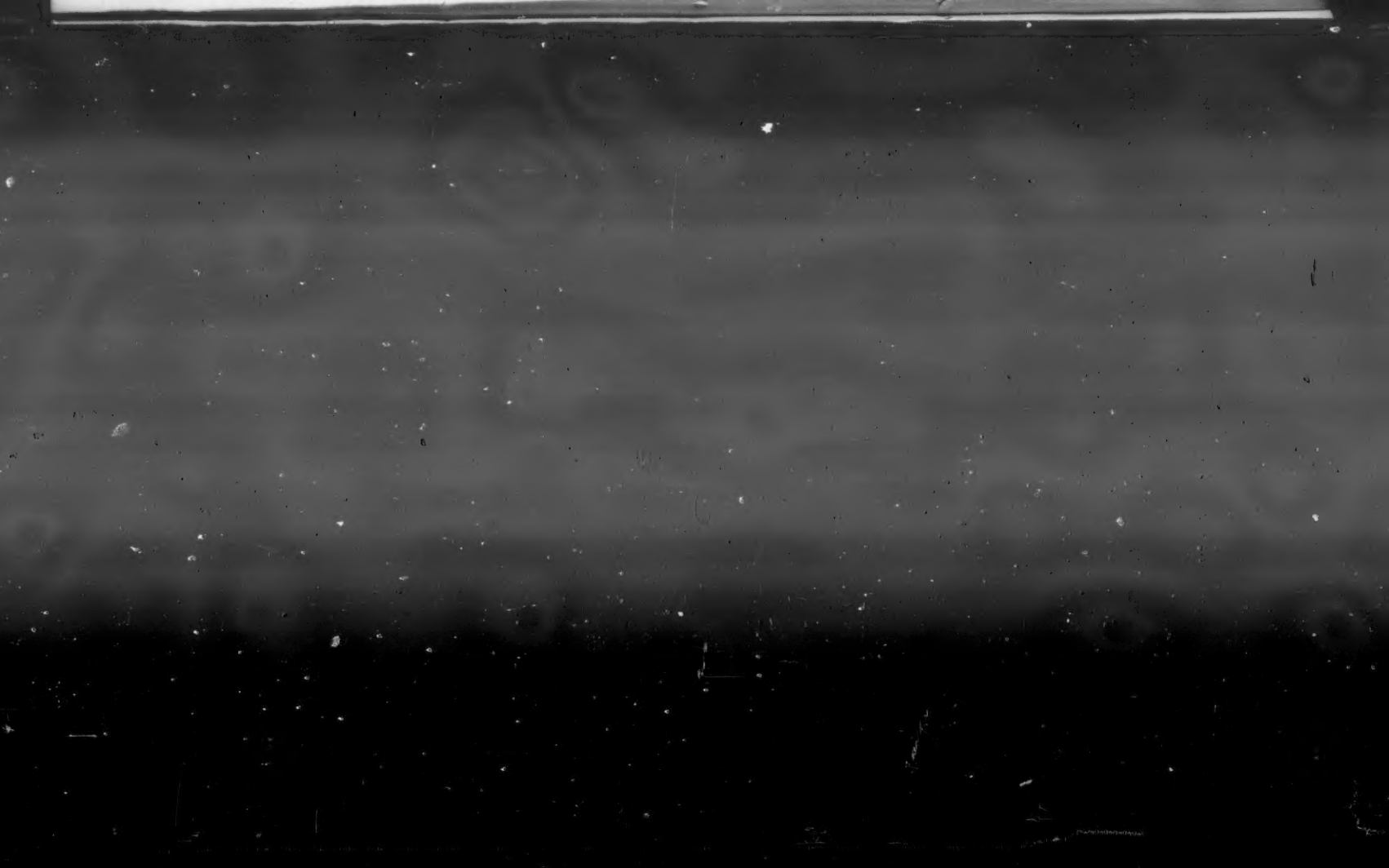
tory, especially conchology, in 1826, when he built a yacht for the purpose, and undertook a cruise of more than a year's length among the islands of the South Pacific. Returning to Valparaiso, he prepared for explorations along the western coast of southern South America, where he continued for two years collecting in all departments of zoology. In 1835 he started on a new expedition of four years to the Philippine Islands, and made there vast collections in botany and zoology. During the twenty-five years since his return from the East Indies, he was occupied mainly with the arrangement and extension of his collections. He had long been subject to chronic bronchitis and an asthmatic affection, and these were finally the occasion of his death.—*From a notice in Athen., Aug.* 19.

Johann Franz Encke.—Encke, the Director of the Berlin Observatory, died at Spandau, on the 26th of August, 1865. He was born on the 23d of September, 1791, at Hamburg, where his father was a clergyman.

William Rowan Hamilton.—Sir Wm. Rowan Hamilton, Astronomer Royal for Ireland, died on the 2nd of September, at the age of sixty. He became known as a mathematician of extraordinary genius when he was about twenty years old.

His papers on systems of rays, on the methods of dynamics, on algebra looked at as the science of pure time, on discontinuous functions, on equations of the fifth degree, and his *new algebra*, the *Quaternions*, cannot be popularized. But there is one little result of which an idea can be given, one of the earliest of Hamilton's discoveries, and one which alone would carry down his name to posterity. Hamilton found, from optical theory alone, by reasoning on the properties of light, that under certain circumstances a ray, instead of being refracted as a ray, should, if the theory were true, split into a cone of rays. This *conical refraction*, on being looked for under the proper circumstances by Prof. Lloyd, was actually found to exist. No such phenomenon had ever been even imagined; and it may be justly said that no more remarkable triumph of theoretical prediction had then occurred in the history of science. If we must add to it, as a match, the prediction of Neptune by Leverrier and Adams, each of these brilliant feats does honor to the other. Sir W. R. Hamilton was a man of very wide pursuits, and very varied talents; he was a scholar, a metaphysician, and a poet. He was beloved for the kindness of his heart, and respected for the integrity of his character.—*From a notice in Athen., Sept.* 9.

John T. Plummer, M.D.—Dr. Plummer died on the 10th of April, at his residence in Richmond, Indiana, aged 58 years. He was a graduate of the Medical School of Yale College in 1828. While not making chemistry and natural science his special study, he made collections and observations in different departments, and formerly contributed short papers to the pages of this Journal, and to those of the Journal of Pharmacy. He was a member of the Society of Friends (Quakers), and one of the best of men. He was averse to all public show, and quiet and unobtrusive to an extreme. He has left numerous manuscripts, the larger part of which relate to the Society of Friends, of which he was one of the most influential members.



PLATES.

I.—Stereoscopic drawing by hand, Rood, p. 74.—Discussion of Declinometer Observations at Girard College, 1840–45, Bache, 11 diagrams on 2 sheets, pp. 98, 198.—Map of Appalachian mountain system, Guyot, p. 180.—Aurora, as an electric discharge, Marsh, 2 plates, p. 311.

II.—Table of Comparative Sections of U. S. Coal Measures, Lesquereux, p. 119.

IV.—Vertebræ of Eosaurus Acadianus, Marsh, 7 figures on 2 plates, p. 16.—Discussion of Declinometer observations, Girard Coll., 1840–45, Bache, 11 diagrams on 4 sheets, pp. 264, 375, 383.

V.—Iso-magnetic lines of Pennsylvania, for 1842, Bache, p. 359.

VII.—Configuration of Planetary and Lunar systems in Times, Hinrichs, p. 44.

XL.—Eozoön Canadense, p. 361.

APPENDIX.

New Planet.—Prof. Watson, of Ann Arbor, Mich., announces the discovery by him of another planet, on the 9th of October. In a second letter to the editors, dated Oct. 16th, he adds: "I have just received a letter from Prof. Ferguson, from which it appears that the planet discovered by me on the 9th inst. was discovered by Dr. Peters at Hamilton College on the 20th of September. I did not know of this prior discovery until to-day. It seems that Dr. Peters communicated his discovery to the Observatory at Washington, but so far as I know no further announcement was made.

"From a little examination which I have made I feel pretty sure that this planet is identical with *Sappho* (80), discovered by Pogson at Madras on May 2d, 1864, but subsequently lost. The circumstances of the motion of the new planet, as far as I have observed it, agree precisely with the hypothesis of identity with Sappho, according to Pogson's observations from May 3d to May 12th, 1864."

On Prairies.—On the subject of Prairies, some excellent observations are made by H. Engelmann, in volume xxxvi of this Journal, in an article, commencing on p. 384, on the causes producing the different characters of vegetation known as Prairies, Flats and Barrens in Southern Illinois.—J. D. D.

Meteorites.—In a pamphlet on Meteorites (Aërolites) by R. P. Greg of Manchester, England, the author presents the following System of Arrangement:

Class I. AËROLITES.

Order A. Sp. gr. mostly between 1·7—3·2, containing little or no metallic iron.

Trachytic?

- Group *a*. *Carbonaceous;* blackish, and containing carbon.
- Group *b*. *Howarditic;* ash-gray, fine-grained matrix, somewhat resembling trachyte, and containing imbedded crystals of olivine, anorthite, or augite; outside crust highly resinous and pitch-black.
- Group *c*. *Feldspathic;* containing, or consisting of, a mixture of anorthite and augite; crust pitch-black and highly resinous. "Eukrite" of Rose.

Group *d*. *Crystalline;* peridotic, shalkitic, chladnitic; (magnesia-silicates).

Group *e*. *Vesicular*.

ORDER B. Sp. gr. mostly between 3·25 and 3·9.

Group *a*. *Variolitic;* after the manner of the mineral called Variolite.

Group *b*. *Sommitic;* consisting of finely mixed crystalline minerals; something after the nature of the ejected masses of Mt. Somma, Vesuvius.

Group *c*. *Tufaceous;* mixed; spherules numerous. } "Porphyritic" of Shepard.

c_1; composite, crude, &c.

c_2; brecciated, marbled, &c.

Group *d*. *Psammitic;* arenaceous, like sandstone, granular; color yellowish or brownish white; particles chiefly olivinoid; metallic particles freely and visibly interspersed, occasionally with the addition of magnetite and graphite, or veined and stained with rust; Bachmut may be taken as the type. Polished surfaces show more or less of spherules.

d_1; ditto, very fine-grained texture.

d_2; ditto, grayish; texture more compact or tough; New Concord and Lixna may be taken as types.

Group *e*. *Chondritic;* structure coarse-grained, grayish.

e_1; oolitic or pisiform.

e_2; containing small angular crystalline fragments.

Group *f*. *Blanskitic;* after the manner of the Blansko meteorite; color grayish blue, occasionally running into *c* or d_2; probably contains more Labradorite or augite than *d* or d_2. Texture rather uniform.

Group *h*. *Erxlebenetic;* texture fine-grained, tough, and gritty; highly peridotic and metalliferous, with a slight bronze-like luster; this represents quite a peculiar group, of which the Erxleben meteorite may be taken as the type.

CLASS II. SIDEROLITES.

ORDER C. Sp. gr. 4·0—7·0 meteoric iron, containing, or mixed with, stony matter and silicates.

Group *a*. *Pallasites;* olivine, coarsely crystalline.

a_1; ditto, finely crystalline.

Group *b*. Partially or irregularly mixed with silicates.

Group *c*. Containing aërolithic fragments, imbedded in iron showing Widdmannstättian figures.

CLASS III. METEORIC IRONS, OR AËROSIDERITES.[1]

ORDER D. Sp. gr. between 7·0 and 8·0.

Group *a*. *Agrammic;* without line-markings, not lettered when etched with acid.

a_1; nacreous, pearly lustered.

a_2; spotted, or dotted.

Group *b*. *Micrographic;* minutely marked.

Group *c*. *Eugrammic;* distinctly marked; lines parallel to the sides of the octohedron.

Group *d*. *Spora-grammic;* scattered lines, finely marked.

d_1; ditto, coarsely marked.

Group *e*. *Nephelic;* convoluted, or clouded markings.

Group *f*. *Undetermined;* markings doubtful, or altered by artificial heat.

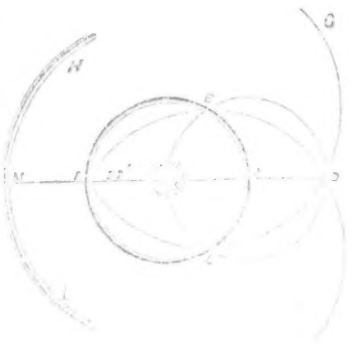
[1] Frequently containing imbedded portions of pyrites, magnetite, graphite, and schreibersite.

ERRATUM.—P. 306, this vol., l. 5 from foot, for 10″ read 10′.

15. *On a solar halo, seen at Crawfordsville, Ind.*, (lat. 40° 03′); by Prof. J. L. Campbell. (In a letter to the Editors, dated Wabash College, Crawfordsville, May 27, 1865.)—Herewith I submit a report of the remarkable appearances in the atmosphere on May 26th, 1865.

The morning was hazy and cool—the thermometer at 5 ranging about 48° to 50°.

About nine o'clock a series of halos or rings began to form about the sun, and continued to increase in brilliancy until near noon—then slowly disappeared during the afternoon—traces being visible at six o'clock in the afternoon. The accompanying diagram is a correct representation of the phenomenon as it appeared at twelve o'clock, noon.



S (Sun), Primary center; A, Secondary center; B and C, Tertiary centers; Radius, SE=22°=AD, SM=44°; MD, Grand axis =88°; Barometer 29·72 in.; Thermometer 70° F.

The most brilliant ring was described about the sun as a center with an angular radius (SE) of twenty-two degrees by careful measurement.

The bands were *white*, *yellow*, *red* and *green*. The white was exceedingly brilliant. The yellow and red were also very bright.

The breadth of this series of bands forming the primary ring was about one and a half degrees.

The arc MLG described about the sun as a center with a radius of forty-four degrees presented less brilliant, but well defined colors in the *reversed* order,—the white band being on the outer circumference, and the green within,—with another inner band of violet.

At A on the circumference of the primary circle, the center of the second circle was located. The radius of this circle was the same as that of the primary—its *circumference passing directly through the sun.*

The ring was chiefly white light, of less brilliancy than the primary, yet very sharply marked throughout its entire circumference.

From D the arcs DF and DG branched off symmetrically with reference to the axis MSD, indicating the centers of curvature at B and C, the intersections of the secondary circle with the primary.

These arcs were of white, well defined, mellow light.

The long continued and well defined manifestation of the phenomenon enabled us to take all our observations very carefully, and to repeat them for further accuracy.

The geometrical relations of the centers of these curves are curious and interesting, and the record of these positions may be of some value in connection with future observations of the same character.

In explanation of these appearances there are some difficulties not hitherto presented in discussing halos. For the present the record of the facts only is made.

16. *British Association at Birmingham.*—The meeting of the British Association opened at Birmingham on the 6th of September, Professor Phillips being the President. The number of members at the meeting during the week following was about 1,400, and besides these there were present 508 ladies and 23 foreigners. The funds received amounted to 2227*l.*; and nearly this amount was set apart for various scientific investigations in astronomy, physics, zoölogy, geology, &c., including 35*l.* for oyster culture. The number of papers read was two hundred and sixty. We have no space in this number for a notice of the Proceedings. The next meeting will be held at Nottingham.

17. *Systema Naturæ of Linnæus.*—By letter from Prof. A. E. Nordenskiold of Stockholm we learn that the Academy of Sciences of Sweden is about to have printed a new photo-lithographic edition of the first edition of Linnæus's Systema Naturæ; and he adds, that "To enable us to judge how many copies may be sold it would be of some interest to have an idea of the probable extent of its sale in the United States." This first edition of Linnæus consists of only 13 to 14 leaves in folio and still contains the rudiments of all his great productions.[1]

18. *New Planet.*—Planet No. ㊾ was discovered on Aug. 25, by Dr. Luther, of the Observatoray at Bilk, near Düsseldorf. On the day of discovery at 10h. 46m. 28s., Bilk mean time, its A. R. was 323° 37′ 49·1″, and its declination N. 14° 20′ 47·1″. It has been named Clio.

19. *Italian Society of Natural Sciences.*—An extraordinary meeting of this Society was held at Spezzia on the 17th of September.

20. *Prof. Berthelot.*—A chair of Organic Chemistry has been founded at the College of France, and Prof. Berthelot appointed to fill the place.—*Reader, Sept.* 2.

21. *Statue of Arago.*—An inauguration of the statue of Arago, erected at his birthplace, Estagel, in the Basses Pyrenees, took place on the 31st of August. His son, dissatisfied that he had not received a special invitation, and because there was no commemoration of his father's political services, declined to be present.—*Reader, Sept.* 9.

21. *Chambers's Encyclopedia.*—Parts 94, 95, 96, 97 of this valuable Encyclopedia, extending to RID., have been issued by the American publishers, J. P. Lippincott & Co.

OBITUARY.

Admiral William Henry Smith.—Admiral Smith died at his residence near Aylesbury, Sept. 9th, at the age of 77. He had acted as President of the Astronomical Society, and of the Geographical Society, Vice President of the Royal Society, and Director of the Society of Antiquarians. He retired in 1825 from naval life, and published in 1844 the "Cycle of Celestial Objects," including the "Bedford Catalogue," an excellent hand book of practical Astronomy, a result of a series of astronomical observations in his Observatory at Bedford. He also published many works or memoirs on Geographical and other subjects.—*From a notice in Reader, Sept.* 16.

Hugh Cumming, died in London, on the 10th of August last, at the age of 74. He commenced his journeyings in behalf of natural his-

[1] If persons desiring the book will so write the Editors of this Journal they will communicate the result to the Swedish Academy.

tory, especially conchology, in 1826, when he built a yacht for the purpose, and undertook a cruise of more than a year's length among the islands of the South Pacific. Returning to Valparaiso, he prepared for explorations along the western coast of southern South America, where he continued for two years collecting in all departments of zoology. In 1835 he started on a new expedition of four years to the Philippine Islands, and made there vast collections in botany and zoology. During the twenty-five years since his return from the East Indies, he was occupied mainly with the arrangement and extension of his collections. He had long been subject to chronic bronchitis and an asthmatic affection, and these were finally the occasion of his death.—*From a notice in Athen., Aug.* 19.

JOHANN FRANZ ENCKE.—ENCKE, the Director of the Berlin Observatory, died at Spandau, on the 26th of August, 1865. He was born on the 23d of September, 1791, at Hamburg, where his father was a clergyman.

WILLIAM ROWAN HAMILTON.—Sir Wm. Rowan Hamilton, Astronomer Royal for Ireland, died on the 2nd of September, at the age of sixty. He became known as a mathematician of extraordinary genius when he was about twenty years old.

His papers on systems of rays, on the methods of dynamics, on algebra looked at as the science of pure time, on discontinuous functions, on equations of the fifth degree, and his *new algebra*, the *Quaternions*, cannot be popularized. But there is one little result of which an idea can be given, one of the earliest of Hamilton's discoveries, and one which alone would carry down his name to posterity. Hamilton found, from optical theory alone, by reasoning on the properties of light, that under certain circumstances a ray, instead of being refracted as a ray, should, if the theory were true, split into a cone of rays. This *conical refraction*, on being looked for under the proper circumstances by Prof. Lloyd, was actually found to exist. No such phenomenon had ever been even imagined; and it may be justly said that no more remarkable triumph of theoretical prediction had then occurred in the history of science. If we must add to it, as a match, the prediction of Neptune by Leverrier and Adams, each of these brilliant feats does honor to the other. Sir W. R. Hamilton was a man of very wide pursuits, and very varied talents; he was a scholar, a metaphysician, and a poet. He was beloved for the kindness of his heart, and respected for the integrity of his character.—*From a notice in Athen., Sept.* 9.

JOHN T. PLUMMER, M.D.—Dr. Plummer died on the 10th of April, at his residence in Richmond, Indiana, aged 58 years. He was a graduate of the Medical School of Yale College in 1828. While not making chemistry and natural science his special study, he made collections and observations in different departments, and formerly contributed short papers to the pages of this Journal, and to those of the Journal of Pharmacy. He was a member of the Society of Friends (Quakers), and one of the best of men. He was averse to all public show, and quiet and unobtrusive to an extreme. He has left numerous manuscripts, the larger part of which relate to the Society of Friends, of which he was one of the most influential members.

GENERAL INDEX

OF

VOLS. XXXI—XL, SECOND SERIES.

NOTE.—In the statement of the number of the volume, the XXX (thirty) is omitted. The names of minerals are inserted only under the word MINERAL. The references to articles on Botany, Geology and Zoology, are grouped under these words, but at the same time are in general inserted in their places elsewhere.

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APPENDIX.

New Planet.—Prof. WATSON, of Ann Arbor, Mich., announces the discovery by him of another planet, on the 9th of October. In a second letter to the editors, dated Oct. 16th, he adds: "I have just received a letter from Prof. Ferguson, from which it appears that the planet discovered by me on the 9th inst. was discovered by Dr. Peters at Hamilton College on the 20th of September. I did not know of this prior discovery until to-day. It seems that Dr. Peters communicated his discovery to the Observatory at Washington, but so far as I know no further announcement was made.

"From a little examination which I have made I feel pretty sure that this planet is identical with *Sappho* ⍟, discovered by Pogson at Madras on May 2d, 1864, but subsequently lost. The circumstances of the motion of the new planet, as far as I have observed it, agree precisely with the hypothesis of identity with Sappho, according to Pogson's observations from May 3d to May 12th, 1864."

On Prairies.—On the subject of Prairies, some excellent observations are made by H. Engelmann, in volume xxxvi of this Journal, in an article, commencing on p. 384, on the causes producing the different characters of vegetation known as Prairies, Flats and Barrens in Southern Illinois.—J. D. D.

Meteorites.—In a pamphlet on Meteorites (Aërolites) by R. P. GREG of Manchester, England, the author presents the following System of Arrangement:

CLASS I. AËROLITES.

ORDER A. Sp. gr. mostly between 1·7—3·2, containing little or no metallic iron.

Trachytic?

- Group *a*. *Carbonaceous;* blackish, and containing carbon.
- Group *b*. *Howarditic;* ash-gray, fine-grained matrix, somewhat resembling trachyte, and containing imbedded crystals of olivine, anorthite, or augite; outside crust highly resinous and pitch-black.
- Group *c*. *Feldspathic;* containing, or consisting of, a mixture of anorthite and augite; crust pitch-black and highly resinous. "Eukrite" of Rose.
- Group *d*. *Crystalline;* peridotic, shalkitic, chladnitic; (magnesia-silicates).
- Group *e*. *Vesicular.*

ORDER B. Sp. gr. mostly between 3·25 and 3·9.

Group *a*. *Variolitic;* after the manner of the mineral called Variolite.

Group *b*. *Sommitic;* consisting of finely mixed crystalline minerals; something after the nature of the ejected masses of Mt. Somma, Vesuvius.

Group *c*. *Tufaceous;* mixed; spherules numerous. } "Porphyritic"
c_1; composite, crude, &c. } of Shepard.
c_2; brecciated, marbled, &c.

Group *d*. *Psammitic;* arenaceous, like sandstone, granular; color yellowish or brownish white; particles chiefly olivinoid; metallic particles freely and visibly interspersed, occasionally with the addition of magnetite and graphite, or veined and stained with rust; Bachmut may be taken as the type. Polished surfaces show more or less of spherules.

d_1; ditto, very fine-grained texture.

d_2; ditto, grayish; texture more compact or tough; New Concord and Lixna may be taken as types.

Group *e*. *Chondritic;* structure coarse-grained, grayish.

e_1; oolitic or pisiform.

e_2; containing small angular crystalline fragments.

Group *f*. *Blanskitic;* after the manner of the Blansko meteorite; color grayish blue, occasionally running into *c* or d_2; probably contains more Labradorite or augite than *d* or d_2. Texture rather uniform.

Group *h*. *Erxlebenetic;* texture fine-grained, tough, and gritty; highly peridotic and metalliferous, with a slight bronze-like luster; this represents quite a peculiar group, of which the Erxleben meteorite may be taken as the type.

CLASS II. SIDEROLITES.

ORDER C. Sp. gr. 4·0—7·0 meteoric iron, containing, or mixed with, stony matter and silicates.

Group *a*. *Pallasites;* olivine, coarsely crystalline.

a_1; ditto, finely crystalline.

Group *b*. Partially or irregularly mixed with silicates.

Group *c*. Containing aërolithic fragments, imbedded in iron showing Widdmannstättian figures.

CLASS III. METEORIC IRONS, OR AËROSIDERITES.[1]

ORDER D. Sp. gr. between 7·0 and 8·0.

Group *a*. *Agrammic;* without line-markings, not lettered when etched with acid.

a_1; nacreous, pearly lustered.

a_2; spotted, or dotted.

Group *b*. *Micrograminic;* minutely marked.

Group *c*. *Eugrammic;* distinctly marked; lines parallel to the sides of the octohedron.

Group *d*. *Spora-grammic;* scattered lines, finely marked.

d_1; ditto, coarsely marked.

Group *e*. *Nephelic;* convoluted, or clouded markings.

Group *f*. *Undetermined;* markings doubtful, or altered by artificial heat.

[1] Frequently containing imbedded portions of pyrites, magnetite, graphite, and schreibersite.

ERRATUM.—P. 306, this vol., l. 5 from foot, for 10″ read 10′.